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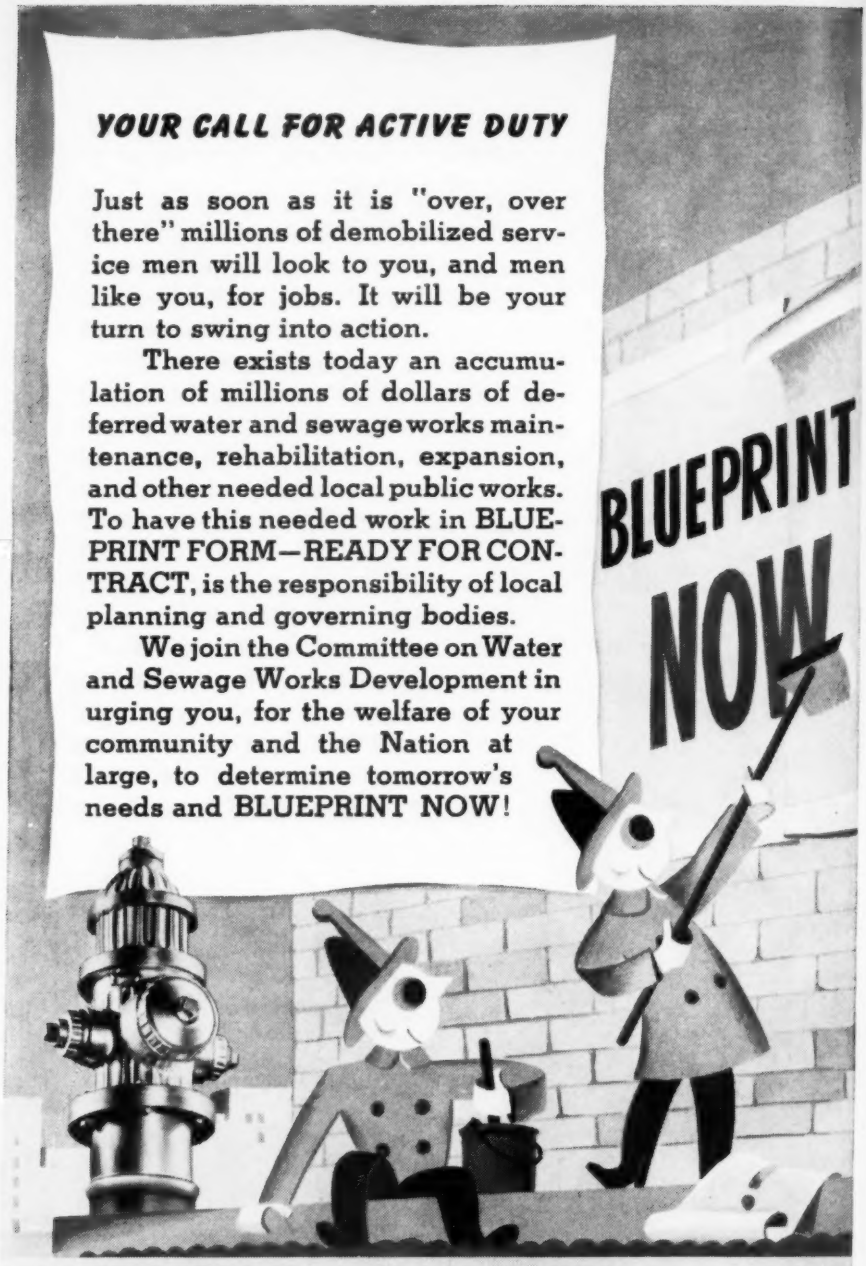

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Vol. 36 April 1944 No. 4

Grounding of Electric Circuits on Water Pipe

Statement of A.W.W.A. Policy

THROUGHOUT the period that the protective grounding of electric circuits on water pipes has been advocated as a safety measure, the American Water Works Association has attempted to cooperate with those supporting the practice, so long as damage to water pipe or water quality did not occur. In recent years, it has appeared that a tendency exists to assert the propriety of increasing the travel of current over water pipe, not as a matter of additional safety, but as a means of simplifying certain problems derived from the use of electric current and from the equipment and devices conventionally installed or advocated for approval and use in the electric utility field.

The preparation and publication of an interim report by the "Joint Research Committee on Grounding" has therefore been taken as an occasion for the Board of Directors of the A.W.W.A. to discuss the subject and to record its opinions on behalf of the North American Water Supply Industry. The statement follows:

The American Water Works Association has cooperated in the activities of the American Research Committee on Grounding through the appointment of representatives to the committee, and through the active participation of these representatives in the work that the committee has accomplished. As evidence of that participation, the 1944 interim report of the committee is published in the A.W.W.A. Journal. The phraseology of this report clearly indicates that it is not a final report of the committee.

The grounding of electric wiring systems on water service pipes involves matters of policy as well as engineering and technical facts. While the representatives of the American Water Works Association on the Research Committee have participated in the preparation of this report and the A.W.W.A. gives the report circulation through publication in its Journal, it considers it necessary to record definitely certain opinions upon the subject.

(1) This Association will cooperate in all practices which lead to greater safety for the public. It will continue to consider all proposed measures,

which are called safety measures, to see (1) whether such measures have the importance attributed to them by their proponents; (2) whether the proposed practices are effective; and (3) whether the practices are being proposed upon grounds of economy rather than fundamental merit.

(2) This Association notes, on behalf of water works executives generally, that the grounding of electric services upon water pipes is understood to be desirable in the interest of safety of the users of electric current. It observes that water departments and companies do not install such connections; derive no benefit from them; may be damaged by them; and tolerate them only because of their reputed importance in providing electric service safely. It further observes that grounding of electric service lines through automatic safety switching has been widely used in England, Europe and Australia.

(3) It maintains its general objections to the systematic interchange of stray electric current from electrical distribution systems to water pipes, and its unqualified opposition to the use of the water pipe system or its connections as an essential or integral current-carrying part of any electrical distribution system. It is, however, not objecting to the current interchanges which occur during comparatively brief and infrequent intervals when ground connections are fulfilling their specific protective purposes.

(4) It considers that the present indifference of the various agencies, interested in protective grounding, in the maintenance of and continued efficiency of grounding connections is unfortunate. Such connections appear to be, after their installation and original inspection, relinquished to the customer/owner as his responsibility, although, in the main, such customers/owners do not know the purpose of the connections and do not know whether or not they are affording the protection for which they are installed. The electric utility interests, the insurance interests, and the municipal inspection agencies share a joint responsibility for the maintenance of protective grounding installations. The water works industry has not assumed, and does not now assume, any responsibility in the matter, except it be in the protection of the structures which it maintains in order to serve its customers.

(5) Water purveyors assume no direct or indirect responsibility or obligation in connection with the installation of water pipe ground connections, or for the maintenance of the integrity or continuity of any grounding attachment or connection made to a water pipe system.

(6) Water purveyors reserve the right to use non-metallic piping or pipe jointing materials for mains, for service piping, or for house piping, without *primary* regard to the effect that this may have on electrical grounding problems. It is the water works operator's obligation to operate and maintain his system at a maximum of efficiency and effectiveness from a water works service and economic viewpoint.

The above statements of policy have been officially approved by the Board of Directors of the American Water Works Association and are recorded herewith for public information.

HARRY E. JORDAN,
Secretary.

March 1, 1944

Interim Report of Investigations

American Research Committee on Grounding

THE American Research Committee on Grounding was formed several years ago by a group of interested organizations to investigate the subject of grounding electrical distribution circuits for safety purposes, as prescribed by the National Electrical Code, with particular reference to any harmful effects from grounding such circuits on water pipes. The circumstances of the Committee's origin and the scope of its investigations are described herein.

In carrying out its assignment the Committee has followed two main lines of investigation, (1) field studies of specific cases referred to it by operating water companies, and (2) laboratory tests.

In respect to the field studies, the Committee has investigated all cases it has been able to learn of and to which it has had access, where impairment of water or water supply facilities has occurred under circumstances such that the water purveyors have suspected that the trouble might have been caused by electric currents resulting from such grounding. Only cases involving alternating current systems have been reported to the Committee.

The Committee is continuing its investigations but a large amount of data have already been accumulated, from which the following findings and tentative conclusions are drawn:

Outline of Results

General

Protective Grounding

Protective grounding of alternating-current secondary distribution circuits has been a recognized practice since 1913 and at present almost universal.

Incidental Contacts

In most premises there are incidental metallic contacts between electrical conduit or armored cable and the various building piping systems, which in effect ground the electrical system to the water pipes.

Current on Water Pipes

In general, where there are water pipes in premises supplied by alternating current, part of the current will flow over the water service pipes. This is usually so where more than one customer is supplied from a single transformer as is generally the case in built-up areas such as are served by public water systems.

Submitted January 1944, by H. S. Warren, *Chairman*, 420 Lexington Ave., New York, N.Y.

Current on Gas Pipes

In general the flow of alternating current on gas service pipes was very low. In two cases, however, the gas pipes carried substantial current, one of these being a welded main.

Current on Drainage Pipes

In the investigations, drainage or soil pipes were too large in diameter for the use of the clip-on ammeter, but generally the distribution of the test load current was such that it would appear these pipes did not carry current. In general, soil or drainage pipes of cast iron end about five feet outside the wall of the building, being continued with tile pipe.

These items of General Data are discussed in greater detail later in this report. (See page 388).

Classification of Field Cases Investigated

About one hundred cases have been investigated by the Committee from 1936 to date. (See page 394.)

Impairment of Quality of Water

About a third of the cases investigated were blue water complaints. These cases were mostly at premises with copper tubing in areas served by untreated well water classified as aggressive. The fact that aggressive waters, particularly well waters, may cause blue water with copper or brass piping was, of course, well known in the water works field, but it was not generally appreciated that slightly aggressive or border-line waters could also give trouble. Trouble was experienced regardless of whether the pipes carried current or not. In three cases, current was taken off the pipes but this did not eliminate the blue water condition. In one case where subsequent to the complaint, the wate had been subjected to treatment fo reducing aggressiveness, the committe found the blue water trouble had dis appeared. (See page 395.)

In the nine cases where rusty wate complaints were referred to the committee, the house piping, and in mos cases the service piping, were of copper or brass. (See page 395.)

There were only six other cases involving quality of water. Four o these were complaints of taste or odo and two were of sediment in water In none of these cases was the trouble found to be due to current on the pipes (See page 396.)

Corrosion of Pipes, Tanks, Etc.

Eleven cases related to the failure of copper tubing or high copper alloy hot water tanks. Nine of these failures occurred in two areas. In most cases there was no current on the tank or pipe that failed. The water supply in most of these cases was classified as aggressive. (See page 397.)

Troubles on brass pipe (six cases) were mainly leaky joints and dezincification. Investigation of leaky joints indicated that most of them were due to poor workmanship. Dezincification occurred on pipes that did not carry current as well as on pipes that did carry current. (See page 397.)

Failure of iron pipes (five cases) mainly involved boiler tubes. The failure was probably due to differential aeration effects or galvanic action between the tubes and the copper heat transfer unit in the boiler. (Page 397.)

One failure of lead pipe was due to the corrosive action of free lime in the cement on the outside of the pipe. There was no current on the pipe. (See page 398.)

Electric Shock and Sparking

In four cases of electric shock or sparking, two were due to defective wiring and two were due to absence of protective grounding. (See page 398.)

Two cases of shock and one of gas ignition by sparking were due to radio grounds on the house piping. In these cases the current in the grounding conductor was due to a filter condenser in the radio set connected across the power circuit.

Laboratory Tests

Laboratory tests of weight loss of metallic specimens which simulated pipes and laboratory tests on polarization indicated that alternating current did not affect the corrosion of pipes. These tests were made in weak salt solutions. (See page 401.)

Findings

1. Grounding of electric power and lighting circuits is necessary for the safety of the customers and their property.

2. In general, grounding to metallic water pipes provides the highest degree of safety. This is because the resistance to ground of such pipes is generally lower than any other grounded metal body present, and for protection by grounding the lowest resistance grounding electrode available should be used.

3. The water piping system is of necessity in parallel with the grounded conductor of the electric distribution system. The division of current between the two systems is affected by a number of factors, one of which, but not necessarily a controlling one, is the resistance of the jointing material used in the water mains.

4. In many cases the removal of alternating current from water service pipes or mains is difficult to accomplish.

5. The voltage which produces the current over the grounding conductor and water pipes under normal conditions appears to be of the order of 3 to 4 v. In one instance with a long service entrance cable and water service pipe, approximately 8 v. were found.

6. No conclusive evidence has been found to date that alternating current of the magnitude measured by the Committee has any appreciable detrimental effect on the pipes or on the water in the pipes.

7. The galvanic couples which exist in most piping systems, between dissimilar metals, or between dissimilar surface conditions on the same piece of metal, may produce currents in the water which are much greater than those produced in the water by current flowing along the pipes.

8. The troubles from blue water which the Committee has investigated have been found to be due mainly to the action of untreated aggressive well waters on copper tubing. Small variations in impurities permitted in the manufacture of copper tubing seem to affect the extent to which blue water troubles may be experienced.

9. Numerous leaky joints in yellow brass pipe systems were found due to poor workmanship in installation. This gave rise to some dezincification at these joints. Dezincification was also observed in some yellow brass pipes at locations other than joints.

10. If the recognized practice of grounding is not followed, there may be a hazard due to electric shock, ignition of gas and sparking. If the grounding connection is not made on the street side of the water meter, there should be a bonding jumper

around the meter to insure continuity of the grounding circuit when the meter is disconnected.

11. In about 10 per cent of the cases, the grounding installations were found to be defective. (For additional comment, see page 392.)

12. In order to insure more effective and permanent grounding connections to water pipes, more satisfactory methods and devices than are now available should be developed.

The evidence on which the above findings are based, the methods employed in the field and laboratory investigations, and related technical information about grounding and electric current distribution, together with the historical background to this subject, are all given later in this report.

Events Leading Up To the Formation of the American Research Committee on Grounding

In the early days of the National Electrical Code, there was no mandatory grounding requirement. As a result of a study by a Committee of the American Institute of Electrical Engineers, grounding for ordinary alternating-current distribution circuits was strongly recommended. The first National Electrical Code to contain a mandatory grounding requirement for circuits was the edition of 1913.

In 1920, the American Water Works Association sanctioned protective grounding connections to water pipes. There had been considerable opposition to electrical interconnections between water pipe systems and electrical distribution networks. The electrical interests, however, stressed the necessity for such grounding connections as the only practical means of protecting life and property. On being assured that such connections would not entail any hazard, inconvenience or difficulty as far as the water operators were concerned, the A.W.W.A., at its 1920 Convention, approved the following resolution:

Be it resolved that the American Water Works Association approves the practice of grounding the secondaries of lighting transformers to the water pipes, providing that the grounding is done in accordance with the rules of the National Electrical Code and National Safety Code.

In 1927 the A.W.W.A. adopted another resolution which reads:

Be it resolved, that the American Water Works Association in convention assembled, hereby modifies its 1920 endorsement of the grounding of the secondaries of lighting transformers as follows:

(1) The American Water Works Association approves the practice of grounding the secondaries of lighting transformers on water pipes for the purpose of safeguarding life and property, provided that appreciable electric current flows over such ground connections only during comparatively short and infrequent intervals when the ground connections are fulfilling their specific protective purposes, and provided that such ground connections impose no responsibility upon the pipe owning company.

(2) The American Water Works Association is opposed to the use of water pipes as electrical conductors, except as noted above, and since experience with certain power distribution practices which have come into use has shown that grounding may result, and in many cases has resulted, in hazard to the pipe structures and water works employees, it hereby withdraws its former general endorsement of grounding on water pipes.

At the convention of the A.W.W.A. in 1933, a paper entitled "Promiscuous Electric Grounding on Water Service

Pipes and Mains," was presented by Hill, Meyerherm and Cowles.* This paper briefly discussed the electrical phenomena of electrolysis. It mentioned a number of situations of pipe corrosion, discoloration and taste and odor of water, some of which apparently were cleared up by removing various electrical grounding connections, including grounds to radio sets. The authors stated that "the examples cited . . . are admittedly rather scattered and inconclusive. . . ." They also pointed out "the need for further study and investigation."

Subsequently, in 1935, the A.W.W.A. adopted a resolution which read in part as follows:

> Therefore be it resolved that the American Water Works Association in Convention assembled hereby revokes and rescinds any and all previous approval or sanction of the practice of grounding electric light and power circuits on water pipes for protective or other purposes.

In view of this resolution, the A.W.W.A. would not approve the grounding provisions of the 1935 Code as adopted by the Electrical Committee of the National Fire Protection Association and submitted to the ASA for approval. In the discussions which followed, the idea was advanced that the A.W.W.A. would withdraw its opposition to the proposed Code, provided the whole question of grounding was referred to a Committee of representatives from national organizations for detailed study in a fair, impartial and scientific manner.

Toward the latter part of 1935, it was mutually decided that the A.W.W.A. and the Edison Electric Institute, the two organizations most directly and vitally concerned with the grounding problem, would jointly invite representatives of other interested groups to meet together for the purpose of discussing the situation with the hope that the meeting might agree upon some form of permanent organization for this specific problem.

As a result, the American Research Committee on Grounding was organized on March 17, 1936, under the sponsorship of the A.W.W.A. and the Edison Electric Institute. At the organization meeting there were twenty-eight persons present representing eighteen national organizations. The participating organizations are listed in Appendix No. 1. H. S. Warren was elected permanent Chairman and C. F. Meyerherm was elected Secretary and Treasurer. The following two resolutions were adopted:

1. To investigate and report upon, as conclusively as may be

   (a) Electrical grounding connections made to water, gas or drainage pipes, with respect to the effects of any kinds of electrical current thereby caused to flow upon,

   (1) the pipes,
   (2) the contents of the pipes, and
   (3) fire and personal hazards;

   (b) Conditions in the electrical circuits involved which produce current flow over pipes;

   (c) Measurement of stray currents; and
   (d) Efficiency of electrical grounding.

2. That a Technical Subcommittee be formed for the actual conduct of field and laboratory work under the foregoing scope, and that the following organizations be invited to participate with the understanding that they will be expected to contribute in money and personnel toward the conduct of the work of the Committee:

   American Water Works Association
   Edison Electric Institute
   American Standards Association, Telephone Group
   American Gas Association

*Jour. A.W.W.A., 25: 1418 (1933).

American Society of Sanitary Engineering and/or National Association of Master Plumbers

and that the Bureau of Standards be requested to participate in the work of this Technical Subcommittee.

The Technical Subcommittee, after duly considering its assignment, recommended the following program:

1. To contact various water purveyors within a radius of 100 mi. of New York City to report such cases which in their opinion may be due to grounding of electrical circuits on water pipes.
2. That a working committee be appointed to investigate these complaints in cooperation with the local electrical and water organizations.
3. To obtain and analyze available information relating to electrical and galvanic effects.
4. That interested organizations carry on some laboratory experiments relating to this subject.

The program thus recommended has been generally followed and the results to date are given in this report.

As indicated by Resolution 1, the chief duty of the Committee is to determine if the grounding of electrical circuits on water pipes creates adverse effects on the pipes or the water in the pipes. It is not the primary function of this Committee to pass on the adequacy or the quality of the water supply nor on the adequacy of the plumbing practices followed. Since, however, both the nature of the water and the type of plumbing has a bearing on the problem, consideration has been given to both of these items.

That damage is caused by direct current electrolysis where stray current leaves water mains for earth is well understood. This question was thoroughly considered by the American Committee on Electrolysis and others. Our Committee has not studied the question of stray direct current electrolysis. This subject is referred to at this point because statements in published articles in the technical press both in this country and abroad show that many complaints are based on electrolysis effects produced by stray direct currents. Multiple grounding of electric light circuits in stray direct current areas may permit the interchange of direct current over the grounding connections. This is recognized in the National Electrical code and provision is made for the removal of one or more of these grounding connections where the current is sufficient to become objectionable.

Discussion of General Data

Protective Grounding

A ground is a conducting connection, whether intentional or accidental, between an electric circuit or equipment and earth or to some conducting body which serves in place of the earth.

A grounding electrode is a conductor imbedded in the earth used for maintaining ground potential on the conductors connected to it. In the grounding of electric circuits and equipment the grounding electrode is usually the water piping system but it may be a separate ground obtained by driving rods into the earth or by burying large pieces of metal in the earth.

In general driven or buried grounding electrodes have a higher resistance to earth than do water service pipes and water mains.

A grounding conductor is a conductor used to connect an equipment

device or wiring system with a grounding electrode or electrodes. A grounding connection as used in this report refers to the connection between the grounding conductor and the grounding electrode, generally a water pipe.

An electric service is usually grounded on the premises by connecting a wire from the neutral conductor of the circuit at the service cabinet to the water pipe. Metallic enclosures are usually grounded by a metallic connection between the grounded wire and the enclosure at the service box. The grounding of electrical circuits and enclosures is usually done by the electrical contractor who installs the house wiring. In most locations the wiring must be approved by an insurance or municipal electrical inspector before electricity can be supplied and this inspector checks the grounding connections.

Grounding of Electrical Distribution Circuits

At the present time the practice of grounding alternating current secondary distribution circuits on customers' premises where the voltage is not over 150 v. to ground is almost universal not only in this country but also abroad. It is estimated that in this country there are approximately 24,000,000 such grounding connections. When practicable, such grounding is accomplished by connections to water piping systems. It is estimated that about 21,000,000 of these connections are to public water supply systems.

The reasons for grounding electrical circuits are well stated in the 1940 National Electrical Code as follows:

> Circuits are grounded for the purpose of limiting the voltage upon the circuit which might otherwise occur through exposure to lightning or other voltages higher than that for which the circuit is designed; or to limit the maximum potential to ground due to normal voltage.

As an example, a lightning surge may cause a transformer to fail in such a way that the high primary voltage may be impressed upon the house wiring. If the circuit is not grounded, the high voltage may remain on the house wiring indefinitely and thus create both a life and a fire hazard. If the circuit is grounded, the voltage is held to a low value and the resulting current flow to ground will operate protective devices and de-energize the circuit.

Grounding of Metallic Enclosures for Electrical Conductors and Equipment

In regard to the grounding of metallic enclosures of electrical equipment such as conduit, metal boxes and the like, it has long been the practice, with some exceptions, to ground such metallic parts. This is generally done regardless of the voltage or type of circuit involved. In this connection the National Electrical Code states:

> Exposed conductive materials enclosing electric equipment, or forming a part of such equipment, are grounded for the purpose of preventing a potential above ground on the equipment.

Grounding not only limits potentials on metallic enclosures but also is helpful in promptly de-energizing circuits when a fault occurs. To illustrate, if a conductor within an ungrounded conduit should fail in such a way that it comes in direct contact with the conduit, the conduit will become alive and be a hazard to persons who may come in contact with it. If the conduit is grounded and a live wire comes in direct contact with it, the voltage to ground will be kept low and the current

to ground will cause the fuse to operate and disconnect the circuit.

Water Pipe as a Grounding Electrode

The lower the resistance to ground, the better is the protection afforded. The reason why water pipes provide the best grounding electrode and why it is necessary to use them for grounding the electric circuit is well expressed in a paper, "Electrical Grounds on Water Pipe," presented by H. S. Warren * to the New England Water Works Assn.:

> The reason why a continuous metallic public supply water piping system makes the best ground is not because such pipes have water in them but is due to the fact that such a piping system has by far the largest contact surface with the conducting material of the earth. In fact, where such a piping system exists, it is the earth, electrically speaking, for all practical purposes. The hazard to be protected against arises from the fact that voltages may accidentally be set up between different metallic objects in the house and that persons may be subjected to these voltages. Water pipes appear at numerous points through the house and are interconnected or in contact with steam pipes, gas pipes, etc., so that they offer numerous chances for people to get in contact with them. If some other grounding electrode were employed instead of the water pipes, the voltages between electric wiring, apparatus, etc., and this extensive system of pipes might be much larger and, hence, the hazard much greater. The very presence of these piping systems in a house increases the importance of using them as grounding electrodes.

Incidental Contacts

In a large number of situations the electrical system will be grounded to the piping system even though a separate grounding electrode is provided for the electrical system. For example, at many of the premises investigated there were metallic contacts between water pipes (including steam pipes connected to the water pipes) and electric conduits or the armor of armored cable. Some contacts are obtained from direct-connected apparatus such as motors on oil burners and water pumps. Most of the contacts, however, are incidental, such as metallic contacts between conduits, pipes, hot air ducts, etc. In general, it is impracticable to avoid such contacts, particularly where there is metal lath or other steel work in the building. These contacts, in fact, ground the electrical system on the water pipes but they are not reliable and sparking may occur at such points of contact, particularly during lightning storms or at times of power faults. If the two systems are solidly connected, sparking will in general not occur.

Even if the two systems are kept free from contact with each other throughout the entire premises, and the electric circuit is connected to a separate grounding electrode, nevertheless some part of the current flowing in the grounding connection and electrode will flow to the water pipe through the earth. In other words, if the water pipes are not used as the grounding electrodes, and separate grounding electrodes are used, the current on the water pipes will not be completely eliminated.

An investigation made by the Committee at a hospital consisting of several buildings, where the electrical specifications had provided that no conduit should touch steam or water pipes and no wires from conduits or electrical apparatus should be grounded to water pipes, steam pipes or other piping in buildings or tunnels. Separate grounding electrodes were provided for

* J. N.E.W.W.A., **58**: 350 (1934).

every building. Resistance measurements indicated that the grounded conductor was metallically connected to the piping structure in the building, that the piping systems were metallically connected through metal lath and steel work, and that the results were the same as if the conduit had been directly connected to the water piping.

It is therefore evident that incidental contacts may collect and deliver to the water service pipe currents comparable to those normally flowing over grounding connections.

Current on Water Pipes

There has been considerable misunderstanding in regard to current flow over protective grounding conductors, under both normal and abnormal conditions. Prior to the organization of this Committee, it was the common impression that no current flowed over the grounding conductor except when the protective apparatus was functioning. However, water companies often found current on their service pipes independently of protector operation. The reason for this was not immediately apparent, but it has been made clear by this Committee's investigations. Therefore it seems worth while to discuss in some detail the behavior of the currents under various grounding conditions.

Figure 1 shows an arrangement of a transformer supplying only one customer and provided with only one grounding connection to the water pipe. The arrows in this sketch indicate the flow of current. Under normal operating conditions and with the arrangement shown, there would be no current in the grounding conductor or water pipe.

Figure 2 shows an arrangement where two customers are supplied from one transformer but with a load at only one location. The arrows indicate the paths of the current under normal operating conditions. No attempt is made in this sketch to indicate the magnitude of current in each path, since that depends on the relative resistance and will vary with each situation. However, this sketch shows that if two or more customers are fed from one transformer and there is a water pipe ground connection at each customer, there will always be some current over the grounding connection at the water pipe under normal load conditions. The actual amount of current and its location on water piping systems will, of course, vary with each situation and also with change of load. In built-up areas where water pipes are available for grounding, there will

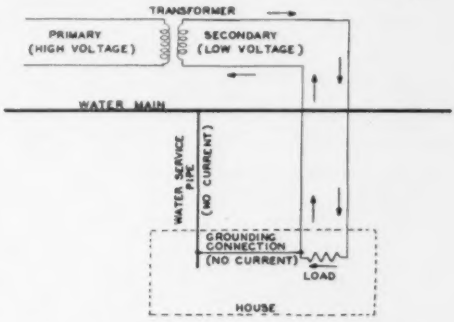

FIG. 1. One Customer on Transformer

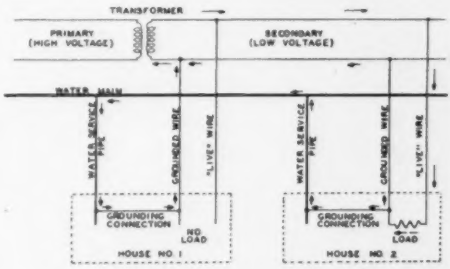

FIG. 2. Two Customers on Transformer

be, as a rule, two or more customers connected to a given transformer. Since this results in two or more grounding connections on the circuit, there will, in general, be some current on grounding connections wherever there is a load on the circuit. In fifty-one situations investigated by the Committee, the current on the water service pipe, outside the point of connection to the grounding conductor, ranged from 0 to 100 per cent and averaged about 20 per cent of the test load current. In four of these cases the current on the service pipe exceeded 50 per cent of the load current. In some instances current was found on the water pipes inside the point where the grounding connection was made, evidently due to incidental contacts between metallic structures within the building.

Figure 2 shows only a two-wire circuit. However, the explanation also applies to a three-wire circuit consisting of two line conductors and one grounded conductor. In the three-wire circuit the current over the grounding conductor will be less since in this case it is a portion of the unbalance in the loads between the two sides of the circuit rather than the total load.

Under abnormal conditions, such as a failure of a transformer or where lightning potentials are impressed on the conductors, there will be relatively large currents in the grounding conductor but such currents will ordinarily last for only an instant. It is this abnormal current which causes primary fuses or overload protectors to operate and isolate the fault almost instantly. During this brief period, the grounding connections are fulfilling their protective functions and maintaining safety under abnormal conditions.

None of the cases investigated by the Committee has been a three-phase system.

Galvanic Action

If two pieces of metal are placed in a chemical solution (electrolyte), but not in contact with each other, each metal will assume a definite potential, the value of which depends on the kind of metal and the nature of the solution. If the two metals are dissimilar, there will be a difference between their potentials. If the two dissimilar metals are brought in contact or connected with each other, the difference in potential between them will set up a current in the solution. This current will cause corrosion of the metal of lower potential (negative electrode or anode). Such a corrosion process is called galvanic action and the combination of the two metals and electrolyte is known as a galvanic cell.

When current flows as mentioned above, a change takes place on the surface of the metal which tends to oppose the transfer of current. The opposing force developed in this manner is known as polarization. It may in some cases, depending on the metals and solutions involved, be sufficient to reduce the current to a very small value but it is never enough to block the current completely.

Every connection in a water piping system between different metals (such as a bronze valve and galvanized pipe, a galvanized boiler with copper pipe, a cast-iron meter bottom with brass top) is in effect a galvanic cell. In addition, differences in the metals themselves or in the surface films on the same piece of metal or in the electro-

lyte may set up galvanic cells whose activity may be of the same order of magnitude as that developed by dissimilar metals. At each such point there is a current flow from one metal through the water in the pipe to the other metal. The metal from which the current leaves is corroded and some of the metal goes into solution. As pointed out in the paper by Hill, Meyerherm and Cowles, there is little polarization with flowing water. In other words, there will be a more or less constant flow of current in the water, depending on the metals involved in the galvanic cell and the electrical resistance of the water.

In the Warren paper previously mentioned, reference is made to tests with pipe couples. In these tests made with brass and iron pipe couples in tap water having a resistivity of 4000-ohm cm., the resulting galvanic current (direct current) was approximately 200 microamperes.

There are a great many galvanic couples involved in piping systems resulting from different metals, different amounts of permissible impurities in the metals, differences in film formation on the same piece of metal, particles carried into the pipes from mains, etc. It is probably the variations in the number and activity of such couples from house to house, which accounts for the wide difference in conditions observed in houses which were otherwise very much alike. The fact that such wide variations can occur in more or less similar situations may not be generally appreciated.

Current in Water Due to Current on Pipes

Pure distilled water is practically a non-conductor of electricity. Most public water supplies contain enough salts and other material to make them conductors to some extent. However, compared with any metal the most conductive water is still an extremely poor conductor. The amount of current which will enter the water due to the presence of current on the pipe will be extremely small compared to the current on the pipe. This is illustrated by a specific case given in the Warren paper mentioned above:

> A simple computation will show how much current will get into the water in a pipe due to the presence of current on the pipe. Assume a ¾-in. standard welded steel pipe and water of 4000-ohm cm. resistivity, a value which is within the range of commercial water supplies. The resistivity of iron and steel has quite a range of values as between different samples, but 11 microhm-centimeters represents a fair value for standard transformer steel. One ampere of direct current on the pipe would mean a voltage drop of 156 microvolts per foot of pipe. With water of the assumed resistivity, the resistance of a water column of 0.533-sq.in. cross-section and 1 ft. long is 35,500 ohms. The same voltage drop in the water as in the pipe would, therefore, correspond to a current of 4.4×10^{-9} ampere or less than one-half of 1/1,000,000 of one per cent of the current in the pipe. In the case of alternating current, the proportion of current in the water would be even less.

It is interesting to compare the current in the water due to one ampere of current along the pipe with with the current set up in the water by a galvanic couple or cell as mentioned above. By comparing the two figures, it will be noted that the galvanic couple introduced 50,000 times as much current in the water as would one ampere of direct current along a ¾-in. iron pipe. In other words, the current in the water produced by the current on the pipe is extremely small compared to the current put in the water by the many galvanic couples which exist in every water system.

Field Work

Obtaining Cases to Investigate

In the paper by Hill, Meyerherm and Cowles mentioned before, a request was made "that any or all information or experience with problems of this or of a similar nature (trouble due to grounding of electrical circuits) be reported to the Association for study and correlation." At the organization and subsequent meetings of this Committee, request was made that complaint cases involving grounding of electrical circuits be referred to the Technical Subcommittee. Letters were written to seventeen water purveyors within a 100-mi. limit of New York inviting them to report cases of such trouble to the Subcommittee. Each report of the Committee, released to the technical press and widely published, carried an appeal to report cases of trouble. Nevertheless, reports have been infrequent so that at times the Subcommittee has had no cases to investigate for periods of several months. As of July 15, 1943, the Subcommittee had covered one hundred and two listed situations. Of these, seventy-eight were complaint cases, the others being situations which the Subcommittee elected to investigate. This means that the Committee has received an average of only thirteen complaints a year to investigate, although it is not to be inferred that all water complaint cases have been brought to its attention. In a number of cases this was not desirable because of customer relations.

Method of Making Field Investigations

Upon receipt of a complaint a group was organized to investigate the case. This group consisted of two or more members of the Subcommittee and one or more persons from the water purveyors and the electric company involved. In general, the following information was obtained:

1. A detailed statement of the complaint from the consumer.
2. Details concerning the source of water supply, treatment, etc.
3. Typical analyses of water supplied.
4. Details of piping system, including street mains, service and house pipes.
5. Type of equipment on the premises, such as hot water tanks and heaters, furnaces, fixtures, etc.
6. Details of electric service, including street circuit, transformer location, house service and house wiring, including grounding.
7. Measurements of alternating currents on pipes and other metallic structures.
8. Measurements of direct current on pipes and structures.

In addition, samples of water were obtained at the premises for analysis.

In a few cases, electrical conditions were altered so that the current was entirely removed from the pipes. Subsequent investigations were made to study the effect of such changes. This is discussed later in more detail (see page 401).

It was understood at the outset that many complexities would be encountered in these investigations and as the work proceeded it was found that many questions arose that had not been anticipated. Such things as variations in types and compositions of materials, in character of water and in rates

of flow of water, in types of water heating equipment and temperature control, the variety of troubles complained of and apparent inconsistencies in the effects, have often made it extremely difficult to determine just what causes were responsible.

The situations investigated may roughly be grouped as follows:

Impairment of quality of water:	
Blue (or green) water including staining of fixtures	34
Rusty or dirty water	9
Taste or odor	4
Sediment in water	2
Corrosion of pipes or equipment:	
Corrosion of copper tubing or high copper alloy water tanks	11
Corrosion of brass pipes or fittings	6
Corrosion of iron pipes	5
Corrosion of lead pipe	1
Electric shock and sparking	7
Miscellaneous	9
Adjacent situations for comparison—No trouble found	14

Discussion of Situations Investigated

Impairment of Quality of Water

Blue Water (34 Cases)

This type of complaint covered approximately one-third of all the cases investigated. With one exception the water service pipes at all locations were of copper tubing. The house piping in 24 cases was copper tubing and in five cases was brass pipe.

The water supply in 25 cases was from wells. In 22 cases there was no treatment except chlorination. In three cases the blue water trouble disappeared when lime treatment was applied to the water supply. (For one case involving blue sediment with lime treated water, see page 396). The water supply involved in at least 23 cases was considered to be too aggressive; that is, some corrosion of copper tubing or brass pipe was to be expected.

In most cases some current was found on the water pipes. On the average about 20 per cent of the test load current was returned over the water pipe. However, in five of these complaints of blue water there was no current on the service or house piping. In three cases the current on the piping was eliminated but the removal of the current from the pipes did not alter the complaint condition.

Rusty Water (9 Cases)

In one case with water pipes of copper, the hot water was rusty after a month of use of a new oil-fired domestic hot water heater. This was apparently due to the iron water tank being improperly galvanized. When the tank was replaced by the manufacturer with a new tank and the former copper connections were changed to galvanized iron, the trouble disappeared. There was some alternating and some direct current on the piping to the hot water tank.

Another of these cases is a good example of the difficulty experienced in making the field investigations. In a large house the piping, including a hot water recirculation system was brass, the hot water tank was copper, the long 1½ in. water service pipe to the street was wrought iron and the pipe from the curb to the main was lead. There was a small amount of alternating current on the service pipe and on a branch pipe to which the

grounding conductor was attached. At the time of the Committee's initial inspection, the rusty water appeared at three different places, but not elsewhere in the house. The most discolored water came from a hot water tap at the most remote point in the house. Several changes in the conditions were tried out and at different times the discoloration has disappeared and reappeared. The explanation of this situation has not yet been found.

In five of the other seven cases both the water services and the house piping were copper or brass and in one of these five cases the service pipe carried no current. In the two remaining cases the house piping was brass or copper but the composition of the water service pipes is not known. In one of these two cases there was no current on the service pipe.

Taste and Odor (4 Cases)

In one case the trouble had disappeared before the committee could make an investigation. In another case a cooling coil was involved which, when by-passed, substantially eliminated the trouble.

The third case involved a dead-end main combined with small usage. There was no current on the grounding conductor or pipes.

In the fourth case the trouble had practically disappeared at the time of inspection. It was attributed to low water in the reservoir.

Sediment in Water (2 Cases)

In one case the sediment was iron rust. The pipes in the house were largely lead and brass, with some iron. The water service pipe was lead-lined iron pipe. Sediment was obtained even when water was flushed for considerable periods through a hose attached directly to the service pipe. The grounding connection was made to a steam pipe and carried part of the load of two houses which were served by one 2-wire service. At the request of the Subcommittee the ground connection was removed for several months. Subsequently, a time switch and a low-voltage transformer were installed to put current on and off the pipe intermittently. These changes in applied current did not correlate with changes in the quantity of sediment found in the water. Samples of water taken from various houses along the same street showed similar sediment but in no case was the quantity as large as it was at the house under inspection.

In the second case the sediment was greenish blue particles. In order to measure the amount of sediment and at the same time eliminate the customer's complaint, a fine mesh strainer was inserted in the water service pipe ahead of the water meter. The amount of sediment was reasonably large initially but it steadily decreased over a period of two months—during August–September 1939. For six months, including the winter period, there was practically no sediment, and then during the period from about August 1 to October 31, 1940, an extremely large amount of sediment was collected. After October 1940, the sediment condition again disappeared. The water supply was treated with lime before and during the early stages of this investigation. Subsequently, about October 1939, sodium hexametaphosphate treatment was applied in addition to the lime. Then in May, 1940, the lime treatment was omitted but the phosphate treatment continued. The interesting features in connection with this case are that by far the largest amount of sediment occurred while

the phosphate treatment was being used by itself and that, with the lime treatment as well as the phosphate treatment, the worst sediment occurred during August and September in two different years. During the entire time that this investigation was being conducted, no change was made in the electric wiring and, therefore, there should have been no significant change in the current being carried by the pipes.

Corrosion of Pipes or Equipment

Corrosion of Copper Tubing and High Copper Alloy Hot Water Tanks (11 Cases)

Five cases involved failure of copper tubing and six involved failures of tanks. Six failures were in one water area and three were in another area. In seven of the locations the Committee found that the water had a blue tint, especially when soap was added. The water supply on all these cases is classified as aggressive. In four cases there was no current on the pipe or tank that failed and in one case there was a small amount of current.

One case where copper tubing within a building failed is of considerable interest. Both the water service and house piping were copper tubing. The service tubing had a firm adhering coating of a protective character on the inside while the house tubing which failed had loosely adhering tubercles on the inside, affording little or no protection. There was current on the service pipe but none on the house piping. Subsequent investigation showed that the phosphorous content, while within specification limits, was twice as great in the house tubing as in the service tubing.

Corrosion of Brass Pipe and Fittings (6 Cases)

A piece of water pipe removed by a plumber showed signs of severe dezincification. No current was found on the pipe which replaced the dezincified pipe. It should be noted that some dezincification was found on yellow brass pipe in several different locations. Dezincification was also found on pipes that did not carry any current. Four cases involved leaks and formation of corrosion products at threaded joints. Upon investigation it was found that the joints leaked due to improper threading of the pipe. Such leaky joints occurred on pipes which did not carry current as well as on pipes which carried current.

In one case a leak was due to corrosion of a brass washer used in a compression fitting for making up copper tubing. This washer was found to be made of so-called free-turning brass which readily corrodes.

Corrosion of Iron Pipes (5 Cases)

Four of these cases involved failure of boiler tubes or associated piping. Electrical measurements did not reveal any alternating currents on the pipes connected to the boilers. Some direct current was found which might have been due to a galvanic couple created by the iron of the boiler and the copper heat transfer unit.

The remaining case was merely an inspection of a situation where the galzanized water service pipe was so badly choked up with rust as to permit the flow of only three gallons of water per minute.

Corrosion of Lead Pipe (1 Case)

The lead water service pipe was corroded on the outside. It failed when

a meter was being reconnected. There was no current on the pipe or the grounding conductor. The corrosion was apparently due to the action of alkali in the cement in which the pipe and ground clamp were imbedded.

Electric Shock and Sparking (7 Cases)

It seems worth while to discuss each case in some detail.

Case 18: A meter man observed sparks when he replaced the water meter at a residence. Investigation showed this was due to a radio ground. The radio ground was opened and 9000-ohm voltmeter inserted between it and the water pipe. The potential measured was 35 v. a-c. and when an ammeter was substituted for the voltmeter a current of 5.4 ma. was observed. The radio set had a line noise filter in which there is a condenser connected between the line conductor and ground. The voltage here involved is in no way hazardous since the high impedance of the condenser limits the current to a few milliamperes. The use of such noise filters is very common in radio sets. It should also be pointed out that a shock can only be obtained when the house piping (with meter out) is completely isolated from ground.

Case 28: A gas company employee was repairing a leak in a small restaurant. In order to make repairs, two regulators and two gas meters were removed. The gas service pipe was plunged but the gas was not shut off at the valve. When one of the regulators was being replaced, the gas flow from the service pipe main ignited and a serious fire occurred. This ignition was attributed to an electric spark. Investigation showed that the electric wiring was proper and grounded to the water pipe. Further investigation showed that the house gas piping was substantially free of grounds when the meter was disconnected. A radio set which was grounded to this gas pipe had a filter with a 0.01-mf. condenser connected across the power leads in the set. This condenser could pass a current of approximately 5 ma. to ground. It seems reasonably certain that a spark resulting from the breaking of this current while replacing equipment caused the ignition of the gas.

Case 31: Plumbers disconnected a steam pipe from the heating furnace and while it was so disconnected received a shock between the steam pipe and furnace. Investigation showed that the radio set was grounded to a living room radiator which was connected to this pipe. This brought about a condition similar to that discussed in detail in Case 18.

Case 30: Due to digging operations in a street in connection with building a sewer, a copper water service pipe had been disconnected from the street main. Subsequent to a lightning storm, the foreman attempted to reconnect the service and received a shock. A water company man equipped with rubber gloves connected the service but in doing so obtained a spark. Investigation showed that a lighting fixture had sparked during the storm and was put out of service. The fixture apparently became energized and in turn energized the armored cable which was in contact with the water pipe. In this case the grounding conductors had previously been cut or broken off. It is of interest to note that, with the grounding conductor properly connected, the low resistance thus provided would have resulted in the operation of the fuse when the

armored cable became energized. Thus the shocks and sparking which were observed about one hour after the storm would not have occurred.

Case 45: This was a case of "flash and electric shock" during the removal of a water meter. Investigation showed that someone had added several single wire extensions from the "hot" wire using the water pipe as the other side of the circuit. In addition, there were several open twisted splices without tape or other protection. These were flagrant violations of the National Electrical Code. It is of interest to note that between the time of complaint and the investigation, a fire occurred in the basement as a result of which part of the basement wiring had been renewed. However, enough of the old wiring was left to indicate clearly what the original condition must have been.

Case 48: This was reported as a blue sediment complaint. In connection with the investigation it was decided that a short section of pipe be removed from the water service about 50 ft. from the house for inspection. The plumber who removed the pipe reported "spark" and "shock" in taking out the piece of pipe. When the pipe was again disconnected in the presence of Subcommittee members noticeable sparks could be observed especially if a hack-saw blade was used to short-circuit the space between the pipe ends. With a load of 10 amp. in the house and with hands thoroughly wet, several of the investigators could just get a slight sensation of shock when the pipe was firmly grasped, one hand on each side of the open ends. The following measurements were obtained:

Current on water service pipe with 10-amp. load in house (gap in pipe closed)	2.5 amp.
Voltage across gap in pipe with 10-amp. load in house *	3 v.
Voltage across gap in pipe during starting of electric washing machine *	10 v.

Case 70: The complaint was that an employee of the water company received a severe electric shock when changing the water meter. Investigation showed that the neutral conductor was open at the house end of the electric service from the pole so that all the current returned via the water pipe. In addition the grounding connection had been made to a cold water pipe about 30 ft. from the meter and no bonding jumper had been placed around the meter as required by the Code and recognized practice. It is of interest to note that this shock would not have occurred if the installation of the grounding conductor had been properly made.

To summarize, the shock and spark situations may be divided into two classes; those due to radio sets which on open circuit can be felt but are not dangerous to life, and those which were due to the fact that the electrical installation was not grounded or was improperly grounded. There were no cases of appreciable shock (other than from the radio sets) where the electrical wiring was in accordance with recognized standards.

Miscellaneous (9 Cases)

None of these cases involved complaints. They merely covered certain

* The above voltage values were relatively high since there was only a 2-wire electric service and it was about 250 ft. long.

investigations and inspections made by the Subcommittee.

One water purveyor had two separate well supplies in the same general area. One supply was treated with lime. The other supply was not treated. The following is a comparison of the analysis of water taken from the treated and untreated supply:

	No Treatment	*With Treatment*
CO_2—free	22.7 ppm	0.4 ppm
pH	5.4	7.1
Alkalinity—eq $CaCO_3$		
Carbonates	0	0
Bicarbonates	10 ppm	25.5 ppm
Hydroxides	0	0
Iron—Total	0.13 ppm	0.58 ppm
Copper	0.64 ppm	0.08 ppm

Note: In both cases the water service and house piping were copper tubing.

In two situations measurements were made on water services supplied by transite mains. These measurements showed that individual services may have a fairly high resistance to ground. However, the resistance at any given point was low due to the fact that many such services were tied together through the grounded neutral power conductor.

Two cases involved a study of current flow on mains in an excavation.

One case involved inspection of grounding arrangements at a hospital as previously mentioned.

One case covered an inspection of 40-yr. old house pipe which was being removed.

In one case electrical grounding was not involved. The premises were located close to a power substation. Apparently at the time of a power fault there was a large current which passed from the water pipe to the gas pipe. At the point of contact between gas and water pipes, they had welded together.

Defective Grounding Installations

In 11 of the situations investigated, the grounding installations were defective. Three of these were due to the ground clamp being poorly attached to the pipe as a result of which there was little or no current over the grounding conductor. In 4 cases the grounding conductor had been removed, broken or cut. In 2 cases no ground had been placed. In one case the connection was made to a steam pipe. In 2 cases the grounded conductor was open so that all the load current returned over the water service pipe.

The relatively large number of defective grounding installations is disturbing and indicates the need of some means whereby better installation and maintenance of protective grounds may be attained.

Ground Clamps

The Subcommittee found that many types of ground clamps were being used and that the clamps were not always well suited for the particular situation involved. In some cases, ground clamps, although they seemed to be tight, nevertheless were not making metallic contact with the pipe. There was also some corrosion at clamps. In one case, this corrosion was sufficiently severe to have caused a pipe failure. With many varied piping conditions encountered both as to piping material used and location, a clamp type of connection will not in many cases provide a connection of permanence and reliability. This question has been given considerable study by the Subcommittee which has come to the conclusion that some form of

lug as an integral part of a pipe fitting would be very helpful towards making a permanent and effective grounding connection for the power service.

Removal of Current From Water Pipes

In most situations encountered where there is current on the water pipes, the disconnection of the grounding conductor from the water pipe will not eliminate the current, since, as explained before, in most premises there are incidental contacts between conduits or cable armor and water pipes. In order to eliminate the current it is necessary to remove the bond between the service cabinet and the neutral conductor, and so arrange the grounding connection that the equipment remains grounded. Unless the neutral conductor is well grounded elsewhere, it is also necessary to run a separate grounding conductor from the neutral to an independent ground, such as a driven pipe. Another method of eliminating the current is to leave the grounding connections undisturbed and to provide a separate transformer to serve only the premises on which the current is to be eliminated. In most existing installations it is difficult to apply either of these methods.

However, the wiring in 4 situations was modified to eliminate the current. In none of these cases did the elimination of the current modify the complaint condition. This observation, combined with the fact that there were complaints in 12 situations where there was no current on the pipes, accounts for the fact that only in 4 situations was the current eliminated by modifying the wiring.

Laboratory Investigation

The committee sponsored certain laboratory tests in regard to polarization and effect of alternating currents on pipes.

Simulated Pipe Tests

These tests were made in the latter part of 1937 and early part of 1938.

The purpose of the simulated pipe tests was to determine under laboratory control and on an accelerated basis whether or not superimposed alternating current on a water pipe containing galvanic couples between dissimilar metal would stimulate or retard the action of these galvanic couples. For use in these tests, electrode assemblies, as shown in the attached Fig. 3, were used. Each electrode assembly consisted of two copper and two zinc pieces placed alternately on a hard rubber rod.

In each test, six electrode assemblies were placed in pans approximately 4 in. wide, 12 in. long and 1½ in. deep and were partially immersed in 400 ml. of a weak salt solution. Electrode assembly No. 1 had no connections between the metal pieces. Electrode assemblies Nos. 2 and 3 had connections between the adjacent metal pieces to permit exchange of current from galvanic action. The remaining 3 electrode assemblies had the metal parts connected in series and had various values of alternating current passing along the electrode assembly.

The results obtained from these tests are given in Table I.

It is evident that a large part of the corrosion found in these simulated pipe tests was due to galvanic action. The results do not indicate that the presence of the alternating current on the electrodes had any material effect on the magnitude of corrosion or loss of metal.

TABLE I

Loss of Weight of Zinc Samples
(Milligrams)

Arrangement of Electrodes	*Test A*		*Test B*		*Test C*		*Avg. Daily Loss Test A, B, C*
	Total	*Per Day*	*Total*	*Per Day*	*Total*	*Per Day*	
No connection	746	26.6	342	16.3	327	15.6	20.2
Connection	2760	98.6	838	39.9	813	38.7	63.0
Connection	2654	94.8	834	39.7	851	40.5	62.0
Connection & 30 mg a-c	2267	81.0	742	35.3	636	30.3	52.0
Connection & 300 mg a-c	2839	101.4	936	44.6	874	41.6	66.4
Connection & 3.0 amp.	2615	93.4	1077	51.3	740	35.2	63.3
Strength of NaCl	1/50		1/500		1/500		
Resistance between metal pieces	1 Ohm		0		0		
Days tested	28		21		21		

Effect of Alternating Current on Polarization

A series of tests were made to determine to what extent alternating current on pipes caused depolarization of galvanic couples which are present in all piping systems. These tests were made between April 1938 and May 1940.

At each galvanic couple or cell in a water pipe, there is a current flow through the water from one electrode metal to the other electrode metal. This current ordinarily corrodes one of the electrodes and also causes metal to go into solution. As a result of the current flow, a change takes place at the surface of the electrode which tends to oppose the flow of current. The opposing force developed in this manner is known as polarization. It is equivalent to a counter emf. It may in cases be sufficient to reduce the current to a very small proportion of the initial value but it is never enough to block the current completely. Other factors such as oxidizing agents tend to destroy the conditions which reduce the current. This action is known as depolarization. In general, any effect which increases polarization will reduce corrosion and any effect which depolarizes or reduces the polarization will increase the corrosion.

In the case of water pipes it is generally recognized that flowing water is an active depolarizer and therefore prevents the slowing down of the rate of corrosion at galvanic couples.

In the following tests, cells consist-

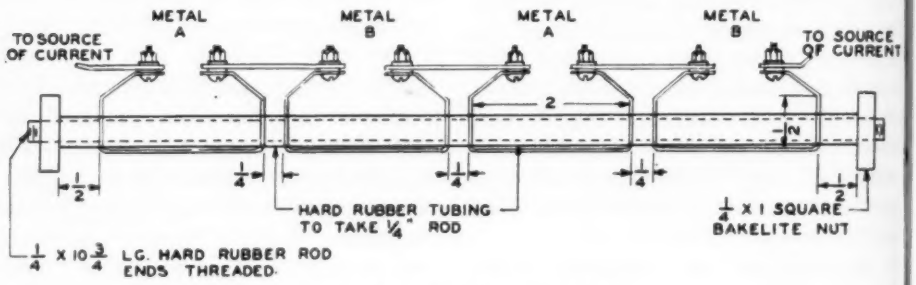

FIG. 3. Simulated Pipe Electrode

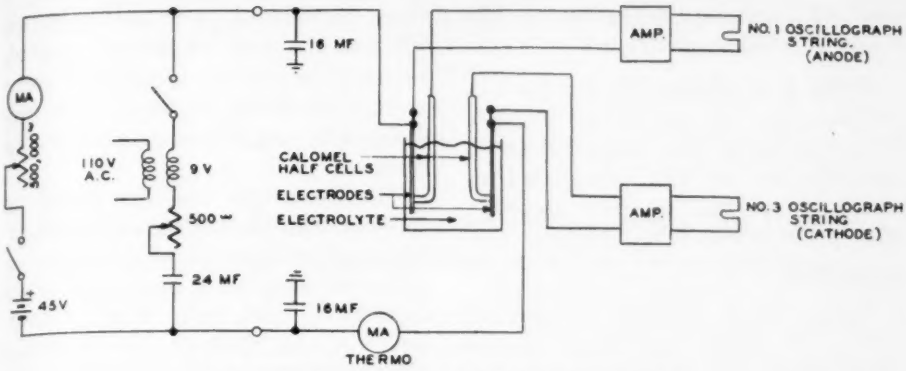

FIG. 4. Schematic Circuit for Polarization Test

ing of two electrodes immersed in a solution of 0.1 normal sodium chloride were used. The general plan followed for these tests is shown in the attached Fig. 4. For tests using direct current only, the switch in the alternating-current supply circuit was left open, and in tests with alternating current only, the switch in the direct-current supply was left open. In the tests with alternating current superposed on direct current, the direct-current switch was closed first and after a proper interval of time the alternating-current switch was closed. With both switches closed, practically no alternating current passed through the direct-current circuit because of the high resistance of the control rheostat. The direct current could not go through the alternating-current branch due to the use of a condenser in this circuit. In all tests with both alternating current and direct current, the direct current was applied first and the alternating current later, usually after an interval of about 100 sec. The polarization potentials were measured by means of calomel half cells and a recording oscillograph.

Figure 5 shows polarization effect with zinc electrodes. It will be noted that the effect of superposed alternating current is small (applied at the 100-sec. point) even though the alternating current was 10 times the direct current.

Figure 6 shows similar curves for copper. Here again the effect is small

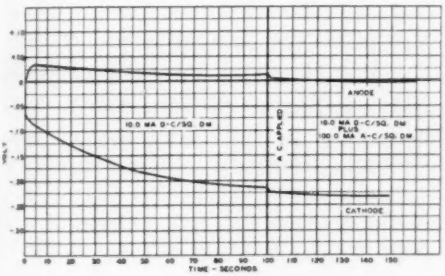

FIG. 5. Effect of Alternating Current on D–C Polarization of Zinc

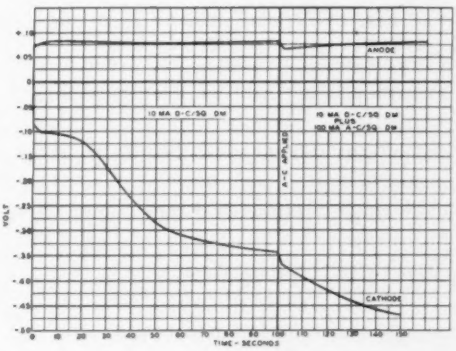

FIG. 6. Effect of Alternating Current on F–C Polarization of Copper

and is practically negligible at the anode (corroding electrode).

While it is admitted that these laboratory tests do not closely simulate field conditions, they nevertheless do establish the fact that superposed alternating currents do not materially alter polarization on water pipes.

Pipe Tests

Several years ago one of the water purveyors conducted tests of various kinds of pipes, some carrying no current, some alternating current and some direct current. The water from the various pipes was tested for metal contents at stated intervals. However, the results obtained were not conclusive. In view of this, the Committee felt that the tests should be repeated, avoiding as far as practicable those conditions which, based on the previous tests, might lead to error in the results.

The Committee has been unable to conduct such tests. However laboratory tests on sections of pipe carrying water are now being conducted by the A.W.W.A. and New York University, in an attempt to determine whether current on the pipes affects the metal concentration in the water delivered from the pipes. So far these tests have not progressed to a point where indicative conclusions can be drawn.

Investigation in England

In 1938, the British Electrical and Allied Industries Research Association, at the request of the Institute of Civil Engineers, prepared a program for research on "Earthing to Water Mains." Early in 1940 this Association published a Technical Report entitled *Critical Resume on the Corrosion of Metal Pipes with Particular Reference to Earthing to Water Mains* by L. H. Daniel, G. Mole, S. Whitehead.

This report is an extensive review of the literature on corrosion and includes many references to publications in this country. Mention is made of the fact that this review was preliminary to making the investigations noted above. No additional information has been obtained from England and it is presumed that no appreciable amount of this work will be carried out until after the war.

Appendix No. 1

List of Organizations Represented at the Meeting of March 17, 1936

American Gas Assn.
American Institute of Electrical Engineers
American Society of Sanitary Engineers
American Standards Assn. (Telephone Group)
American Transit Assn.
American Water Works Assn.
Assn. of American Railroads
Copper and Brass Research Assn.
Edison Electric Institute
International Assn. of Electrical Inspectors
National Assn. of Master Plumbers
National Board of Fire Underwriters
National Bureau of Standards
National Electrical Contractors Assn.
National Electrical Manufacturers Assn.
National Fire Protection Assn.
New England Water Works Assn.
Radio Manufacturers Assn.

A Standard Wage and Salary Administration Plan
Standard Job Classification and Job Descriptions

By Philip B. Niles

IT is the policy of all operating subsidiary water companies of our Company to compensate fairly for their labors all employees who are employed by the individual companies. The development of fair standards of compensation must take into consideration increased ability and experience brought about by application and interest and the just feeling of all men and women that they are entitled to a fair day's pay for an honest day's work. To facilitate the orderly administration of individual wages and salaries for all employees and further to provide for a periodic review of the progress and ability of individual employees, the following plan is adopted for each water company now operating in the System.

The policies specified in this statement become effective on the receipt of this document by each individual water company.

The forms and procedures through which individual wage and salary adjustments are initiated and ultimately made effective will be the subject of a later review in this JOURNAL. This companion article will briefly summarize the type of forms used and the methods instituted for maintaining required controls of payroll adjustments, these controls being required by the orders and regulations issued as a result of wage and salary stabilization. The article will also include a brief discussion of the American Water Works and Electric Company's plan of rating individual employee progress, on which is based recommendations for merit wage adjustments and promotions.

Instructions

The Job Classification and Job Descriptions contained herein cover all the jobs in the System's operating water companies as of January 1, 1944. As new jobs may be added or old abolished, the standard classification and the individual descriptions will be amended accordingly.

An employee will be considered to be in a specific job classification when he spends more than 50 per cent of his time in work covered by such job classification, notwithstanding the fact that he may perform other duties.

All payroll changes of any kind will be recorded in duplicate. The copies are to be transmitted to the Home Office for approval. No payroll change, other than resignations, justifiable discharges and normal replacement hiring

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within ranges and in accordance with the rules of the War Manpower Commission are to be made without the approval of an officer of the Company. Temporary employees may also be hired without prior approval. Such temporary employment must be in accordance with the applicable rules of the War Labor Board and the War Manpower Commission.

The *Standard Wage and Salary Administration Plan* applies to all employees not represented by a collective bargaining agency. However, it more specifically applies to employees coming within the wage and salary regulations of the National War Labor Board.

Salary changes affecting supervisory employees must be submitted for approval and, unless the present rules and regulations of the Salary Stabilization Unit are subsequently changed, application for approval covering any recommended increase will be made to the Stabilization Unit having jurisdiction. No increase in any supervisory salary rate will be made without such approval.

Special Note: Managers of operating water should not recommend *merit increases* in wages or salaries unless they can in good faith assure all concerned that the employee has shown an improvement in the quantity or quality of work or service performed. See definition of "merit increases" below.

Definitions

(1) *Merit Increase*—is an individual wage or salary rate adjustment, made as a reward for improved quantity and/or quality of work or service performed.

(2) *Length of Service Increase*—is an individual adjustment usually made automatically at the end of specified periods of satisfactory service.

(3) *Promotions or Reclassifications*—involve individual adjustments in wage or salary rates which result from transferring an employee into a different job classification. It is inherent that a reclassification may be a demotion as well as a promotion.

(4) *Job Classification*—is the standard job classification and job descriptions adopted January 1, 1942, and revised January 15, 1944, for water works operating companies, and any portion of such job classification as it may apply to any individual water company.

(5) *Automatic Controls*—these are standards approved by the War Labor Board, which control the overall amount of merit increases, length of service increases, or amount of increases due to reclassification, which may be given to any individual employee or group of employees.

(6) *Control Periods*—are the successive twelve month periods beginning July 1, 1943. The automatic controls, defined in No. 5 above, apply to such twelve month periods.

I–A—Merit Increases

The working record and other pertinent personnel information with regard to each permanent employee will be examined periodically—not more frequently than at six month intervals and not less frequently than at twelve month intervals—to determine such employee's qualifications for a merit increase based on improved quantity and/or quality of work or service performed.

There is no measure of quantity for most jobs in water works operation. When this condition exists quality of work must be the only consideration given in establishing the employee's justification for a merit increase.

It is emphasized that the consideration of merit increases at appropriate intervals established by the local manager not more frequently than at six month intervals and not less than every twelve months, includes all employees whether their work is supervisory or non-supervisory in character.

I–B—Length of Service Increases

The policy regarding length of service increases with respect to individual water companies is maintained as at present. It is considered that the automatic increases granted at those water companies which adopted the Defense Emergency Compensation Plan *at the end of six months service* are in fact length of service increases. Such increases will continue to be granted *at the end of six months service* in exactly the same manner as is our present policy in those water companies which have adopted the Defense Emergency Compensation Plan and subsequently combined the Defense Emergency Compensation rate with the basic rate of individual employees.

Water companies may adopt a length of service increase policy applied to new employees when, because of inexperience, such employees are started on the payroll at a rate lower than the lowest rate of the range for the classification in which they are employed. On the completion of a period of satisfactory performance—not to exceed six months—such employees may be rewarded with an automatic length of service increase to the lowest rate of the range for the classification in which they are employed.

There will be no extension of the policy of automatic increases for length of service other than those noted in the preceding paragraph.

I–C—Promotions or Reclassifications

It is the policy of each individual water company whenever possible to fill vacancies by promotion from the presently constituted employee group. These promotions or reclassifications may be made between the various jobs as listed in the Job Classification. In making promotions or reclassifications it is the policy of each individual water company, unless otherwise provided in a collective bargaining agreement, to consider individual merit, experience and ability to perform as the principal criteria in making such promotions or reclassifications, and seniority is only a secondary consideration in determining the individual's suitability for advancement.

It is the policy of each individual water company, unless otherwise provided by a collective bargaining agreement, whenever possible to make every effort consistent with sound operation to provide other work opportunities for employees who would otherwise be laid off because work is no longer available for them. In this type of reclassification the principal criterion should be seniority.

II–A—Automatic Controls

1. Individual merit increases and length of service increases must be made within the job classification rate ranges as presently established.

No individual or combination of merit increases and/or length of service increases granted to any individual employee shall exceed, during any control period, 10 cents per straight time hour or more than two-thirds of the difference between the appropriate minimum and maximum rates within the range in which an employee is located, whichever increase is greater.

This is not applicable to supervisory employees.

2. No individual water company shall grant merit increases or length of service increases to all its employees, excluding supervisory employees, during any control period, the total of which merit increases or length of service increases exceeds the average of 5 cents per straight time hour for all such employees in the establishment.

3. When promoted or reclassified to a higher rated job, employees, but not including supervisory employees, may receive a rate of pay in the new job not in excess of 15 per cent above the rate for the former job, or such employee may receive the minimum rate of the range of the job classification of the new job, whichever is higher. However, when an employee has special ability and experience, he may be paid a rate on the new job within the range for that job corresponding to such ability and experience.

4. The record with respect to each water company will be maintained at the Home Office.

Standard Job Classification
Water Works Operating Companies

I. Plant and Property Protection Group

A. Guard
B. Watchman
C. Caretaker

II. Production Group (Pumping Stations and Collecting Facilities)

A. Fireman
B. Coal Passer
C. Operator
D. Oiler
E. Relief Man
F. Maintenance Man
G. Electrician
H. Machinist
I. Boiler Repairman
J. Plant Laborer
K. Head Engineer

III. Purification Group

A. Filter Operator
B. Softening Plant Operator
C. Relief Man
D. Purification Laborer
E. Laboratory Worker

IV. Distribution Group

A. Casual Laborer (Temporary)
B. Utility Man
C. Subforeman
D. Distribution Laborer
E. Storekeeper
F. Auto Mechanic
G. Reservoir Man
H. Distribution System Record Clerk

V. Outside Commercial Group

A. Meter Reader
B. Collector
C. On-and-Off Man (Inspector)

VI. Meter Shop Group

A. Foreman
B. Meter Repairman

VII. Office and Interior Commercial Group

A. Assistant Cashier
B1. Clerk—Junior
B2. Clerk—Senior
C. Secretary
D. Stenographer
E. Teller
F. Billing Machine Operator
G. Telephone Operator
H. File Clerk
I. Addressograph Operator
J. Office Boy (Girl) Messenger
K. Porter
L. Janitor

VIII. Supervisory Staff Group

A. Manager
B. Assistant Manager
C. Chief Engineer (Production and Purification)

D. Chemist
E. Assistant Chief Engineer
F. Superintendent
G. Assistant Superintendent
H. Cashier
I. Office Manager
J. Distribution System Engineer
K. General Foreman
L. Foreman

IX. Miscellaneous Group

A. Timber Marker
T. Temporary Skilled or Semi-Skilled Worker

X. Piecework Group

A. Coal Unloader
B. Laborer
C. Special Clerk

Standard Job Description
Water Works Operating Companies

I. Plant and Property Protection Group

A. Guard.—Guards are employees charged with the duty of protecting plant and property against sabotage or subversive action during war time.

B. Watchman.—A Watchman is employed to guard plant or property against trespass by unauthorized persons or to protect the public against accident on company property.

C. Caretaker.—A Caretaker is a resident employee having maintenance functions to perform, as well as certain duties as watchman.

II. Production Group (Pumping Stations and Collecting Facilities)

A. Fireman.—A Fireman is an employee charged with the duty of firing boilers, either hand or mechanical, in order to generate steam. He controls feed water equipment and in some cases wheels coal and ashes. He uses gages or other indicators as a guide to efficient operation and maintenance of uniform steam pressure.

B. Coal Passer.—A Coal Passer is an employee whose duty it is to move coal to the boiler and wheel out ashes. He may also assist in cleaning the boilers and boiler equipment.

C. Operator.—An Operator is an employee responsible for operation of machinery and may be generally responsible for operation of entire station. In some cases, an Operator also operates a filter plant, fires boilers and may perform other duties.

D. Oiler.—An Oiler is an employee responsible for proper lubrication of machinery. He usually keeps records of operating statistics and is responsible for keeping machinery and station clean.

E. Relief Man.—A Relief Man is an employee who substitutes for men in categories A, B, C or D during their absences for any and all reasons and is compensated at a specified regular rate for such relief work.

F. Maintenance Man.—In this category are included pipe fitters as well as plant and pump repair men. The duties of maintenance men may include work necessary for repairs to, and general overhauling of, all types of machinery, including steam and internal combustion engines, electric motors, water turbine driven equipment, and also maintenance of boilers and boiler plant equipment and steam and water pipe lines.

G. Electrician.—An Electrician is a skilled employee having knowledge of electric wiring, motors, transformers and other equipment necessary for the operation or supply of electric energy to the plant or plants. This position

requires a practical knowledge of electricity and experience in the safe operation and maintenance of electrical equipment under various conditions.

H. Machinist.—A Machinist is a skilled employee having knowledge of, and experience with, ordinary machine shop tools such as lathes, drills, planers and similar equipment. His duties are to recondition and make new parts for equipment.

I. Boiler Repairman.—A Boiler Repairman is a skilled employee having knowledge of boiler repairs such as the installation of boiler tubes, stoker parts, grates, etc. His principal duty is the general overhauling of boilers, when removed from service.

J. Plant Laborer.—A Plant Laborer is an employee who generally assists in work being done by a skilled man in the plant, and also in some instances acts as janitor and yard man.

K. Head Engineer.—This employee is in charge of the routine operation of the plant, which may also include the purification plant, and also takes a shift, either regularly or to relieve operators during vacations or on off days. His duties usually include keeping records of operating statistics, supervising repairs and maintenance, and controlling plant operation.

III. Purification Group

A. Filter Operator.—A Filter Operator operates filters, handles coagulants and sterilizing agents, checks coagulant and chlorine treatment, makes routine chemical tests for control of treatment, looks after maintenance of filter plant equipment, directs or handles cleaning of coagulant solution tanks and sedimentation basins, keeps plant log reports, cleans filter plant. He may also make bacteriological tests, operate low service, booster and wash water pumps and operate softening plant, as well as zeolite units for boiler feed water treatment.

B. Softening Plant Operator.—This employee handles the softening chemicals, makes routine chemical tests for control of treatment, maintains feed equipment, cleans softening plant, directs cleaning of tanks and basins, maintains plant log and prepares reports, and may operate filter plant and control coagulant treatment. He may also operate low service or booster pumps, and make chemical and bacteriological tests.

C. Relief Man.—A Relief Man takes the shift of the filter plant or softening plant operator on his day off, carrying on all the duties specified under "A" or "B" and is compensated at a specified regular rate for such relief work.

D. Purification Laborer.—A Purification Laborer handles coagulants, cleans purification plant, assists in cleaning basins and overhauling filters, mows the lawn, applies copper sulphate to reservoirs, and assists in repairs and maintenance.

E. Laboratory Worker.—Does simple laboratory work in connection with the operation of the purification facilities including application of various tests and controls; may work on part time basis.

IV. Distribution Group

A. Casual Laborer (Temporary).—A Casual Laborer is an unskilled laborer employed temporarily and usually in connection with the laying of pipe or services. His duties consist mostly, but not exclusively, of excavating and backfilling trenches. He may be employed in emergency maintenance work, other than on the distribution system.

B. Utility Man.—A Utility Man is an employee whose duties are of a general nature, requiring knowledge of the distribution system and skill and experience in installation of service lines, meters, pipelines (both screw and bell and spigot). At times he works with a gang and at other times works alone. He may also act as a calker and yarner.

C. Subforeman.—A Subforeman is an employee in charge of, and may work with, a small gang or gangs installing service lines or small extensions to system. He is responsible for supply of necessary materials to carry on work.

D. Distribution Laborer.—A Distribution Laborer is employed more or less regularly, largely in connection with maintenance of distribution system. His duties include repairing leaks in service lines and street mains, flushing hydrants, painting hydrants, and other distribution system work.

E. Storekeeper.—The Storekeeper is responsible for materials and supplies in his custody and for records as to their receipt and issue, especially as to the group of materials and supplies used in connection with the distribution system. He keeps records of use of materials, segregated by Work Orders or maintenance and repair accounts. He furnishes the office force with information necessary for preparing periodical reports of receipt and issue of materials and supplies.

F. Auto Mechanic.—An Auto Mechanic is an employee whose duty it is to maintain company automobiles or trucks and to make periodic inspections of such equipment and generally to be responsible for the safe operating condition of such equipment.

G. Reservoir Man.—A caretaker of distribution reservoirs. Keeps records of water levels; maintains grounds and fences around reservoirs and may perform other duties.

H. Distribution System Record Clerk.—This employee prepares sketches of pipeline extensions to accompany requests for work orders. He maintains records, maps and other information having to do with the distribution system.

V. Outside Commercial Group

A. Meter Reader.—A Meter Reader reads registers of meters used to measure water supplied to customers, records readings in meter book and may compute quantities of water consumed.

B. Collector.—A Collector makes collections of accounts which are overdue, at locations other than the regular place for payment of bills.

C. On-and-Off Man (Inspector). This employee provides service to customers by opening valves on service pipes and discontinues service by closing valves. He installs and removes meters, inspects customers' premises for purpose of determining numbers and kinds of fixtures or to detect leaks in pipes and fixtures and makes calls for purposes of investigating complaints.

VI. Meter Shop Group

A. Foreman.—A Foreman supervises workers engaged in installing, removing, repairing and testing meters used to measure water supplied to customers. He may also repair meters.

B. Meter Repairman.—A Meter Repairman cleans, adjusts, repairs and tests meters used to measure water, supplied to customers.

VII. Office and Interior Commercial Group

A. Assistant Cashier.—An Assistant Cashier is an office employee who assumes the duties of the Cashier (or Office Manager) in his absence. His regular duties may include those of a supervisory nature and also the clerical work of keeping cash records such as the cash book and preparation of bank deposits. Performs such other office duties as may be assigned or delegated by Cashier or Office Manager.

B–1. Clerk—Junior.—This employee performs one or more of the following functions: prepare bills by hand, operate addressograph, work on customers' accounts and other records, receive customers' applications for service, prepare payrolls and special or regular reports, act as teller, give out information or adjust complaints, operate telephone switchboard, and in general perform other clerical duties necessary for the conduct of a water works business office. This position requires an average standard of proficiency and volume of work performed and is under immediate supervision.

B–2. Clerk—Senior.—A Clerk—Senior performs duties similar to those described under the title of Junior Clerk. Such duties require a better than average standard of proficiency and volume of work performed and a clearly demonstrated ability to perform the clerical duties assigned with a minor amount of supervision.

C. Secretary.—Take shorthand notes and transcribe them on typewriter, copy documents and make stencils on typewriter and take dictation from dictaphone. Perform confidential duties of a clerical nature, dealing with payrolls, contracts and other matters. File letters and documents in confidential files and be responsible therefore and perform other work as assigned by Manager or Office Manager.

D. Stenographer.—A Stenographer takes dictation and does typing, such as letters, vouchers, reports, etc., and may also maintain correspondence files or operate telephone switchboard.

E. Teller.—Receives cash or checks in payment of water bills and receipts bills, makes change, is responsible for cash in cash drawer and proof thereof in accordance with the day's receipts. Position requires courtesy and tact in the handling of numerous daily contacts with the public. May perform other clerical duties as assigned by Cashier or Office Manager.

F. Billing Machine Operator.—Prepare customer bills for water service on standard billing machine in accordance with prescribed standards and routines and under supervision.

Note: This position does not require great proficiency in the machine billing operation as utility bills involve the use of few totals and calculations and are considered a simple billing operation in comparison with various commercial billing routines.

G. Telephone Operator.—Operates telephone switchboard to relay to the different phones in the establishment incoming and inter-company calls and makes connections with outside lines for outgoing calls. May perform other work in connection with filing or other duties as assigned by the appropriate supervisor.

H. File Clerk.—File letters and other documents under a prescribed system of filing as shown on a file chart. Label files and place therein, in accordance with prescribed standards of neatness and accuracy, letters and other printed matter. Check accuracy of file symbols assigned and call attention of supervisor to errors in use of

such symbols. Withdraw files on request and return them to proper position in filing cabinets on their return. Work is carried on under supervision and in accordance with prescribed standards of practice. May perform other clerical or office duties as assigned by appropriate supervisor.

I. Addressograph Operator.—Cut stencils for addressograph plates, operate addressograph machine, maintain addressograph plate files. Change addressograph plates on instructions and do ordinary repairs on addressograph equipment. Work is carried on under supervision and in accordance with prescribed standards of practice. May perform other clerical or office duties as assigned by appropriate supervisor.

J. Office Boy (Girl) Messenger.—Such an employee runs errands and does odd jobs around office.

K. Porter.—This employee is an office handyman. He cleans office and runs errands.

L. Janitor.—This employee cleans office and operates heating plant.

VIII. Supervisory Staff Group

A. Manager.—The Manager is responsible for the local operations of the water company, including the safety and continuity of its operations, its upkeep and maintenance, the furnishing of potable water, the conduct of the business office, the custodianship of local funds and the development and maintenance of harmonious public and personnel relations. Subject to the Board of Directors, the Manager performs his duties under the general direction of the chief executive officer of the Company and in accordance with the established practices and procedures thereof.

B. Assistant Manager.—The Assistant Manager serves under the Manager's direction and assists him in any and all matters having to do with the operation and maintenance of the plant which are delegated to him by the Manager.

C. Chief Engineer (Production and Purification).—The Chief Engineer is in charge of the operation and maintenance of the Company's pumping stations and may also be in charge of the collecting and purification facilities. The Chief Engineer does not stand a watch as an operator and is responsible to the Manager for the safe and efficient operation of that portion of the Company's property under his direction.

D. Chemist.—A Chemist supervises the operation and maintenance of the purification plant, makes chemical and bacteriological tests, investigates complaints, collects samples from distribution system and source of supply, and prepares various plant reports.

E. Assistant Chief Engineer.—The duties of the Assistant Chief Engineer are to assist the Chief Engineer and to perform such specific duties as are assigned to him by the Chief Engineer.

F. Superintendent.—The Superintendent has charge under the Manager and Assistant Manager of operations in one or more districts or divisions of the property. Where there is no Assistant Manager of the plant, the Superintendent may perform the duties ordinarily undertaken by the Assistant Manager.

G. Assistant Superintendent.—The Assistant Superintendent is an employee whose duties are similar to those of Superintendent but who works under a Superintendent.

H. Cashier.—The Cashier, under the supervision of the Manager, is in charge of the office and the employees

engaged in keeping the local records. He is responsible for the regular preparation of the various reports and statements forwarded to the Home Office. He supervises the billing and collection of customers' accounts and the keeping of cash records. He approves disbursements, signs checks and performs such other duties as may be necessary for the functioning of the office.

I. Office Manager.—Office Managers are usually employed in larger water companies, usually those with one or more branches, and his duties are similar to those described under *Cashier*. However, the Office Manager has greater responsibilities than a Cashier, due not only to the larger office staff he supervises in some instances, but due also to the fact that there may be delegated to him more managerial functions.

J. Distribution System Engineer. This employee is sometimes referred to as Civil Engineer. He makes surveys for extensions to, and reinforcing of, the distribution system and has general supervision of the maintenance and operation of the distribution system. The General Foreman works under his orders and instructions. A prerequisite of this position is a scientific education or its equivalent in self-education and long experience in handling water works distribution system problems.

K. General Foreman.—The General Foreman is in general charge and directs the work of the various subforemen and crews working on additions to, and the maintenance and operation of, the water works system.

L. Foreman.—The Foreman is in charge of work carried on in the water works system as delegated to him by his supervisors. This work is of greater importance than work delegated to Subforeman and the Foreman does no work of a character performed by men under his supervision.

IX. Miscellaneous Group

A. Timber Marker.—This employee, sometimes referred to in the lumber industry as a "cruiser," marks trees for sale on Company's water-shed land and may perform other duties in connection with the sale or disposal of standing timber on the Company's property.

T. Temporary Skilled or Semi-Skilled Worker.—This employee—such as carpenter, plumber, mason, electrician, etc., or specialized office worker—is employed for a limited period of time to perform a specific task.

X. Piecework Group.—No job descriptions are included under piecework group as various special jobs are of such wide variation. The three included in the Standard Job Classification are the most usual found in the water works business.

Developing Consumer Co-Operation in Reducing Water Consumption

By Harry R. Hall

FOR at least two years before the entrance of this country into the war, the section of the Washington Metropolitan area which is situated in Maryland had been experiencing a rapid development. Housing developments in areas previously without the usual utility services were rapidly springing up and water and sewer facilities were being extended at the rate of more than 60 mi. per year. As the war continued and the business of the federal government increased, thousands of people were drawn to Washington to take positions in the many newly-created defense agencies. To provide living accommodations for this growing population a considerable acceleration in the construction of housing projects resulted. Actually, according to figures of the United States Census Bureau, the population of metropolitan Washington increased 28.5 per cent from 1940 to the middle of 1943.

In the Washington Suburban Sanitary District, which comprises the area in Maryland immediately adjacent to Washington, covering 114 sq.mi. (with 550 mi. of water mains serving about 145,000 people), the impact of this suddenly increased development resulting from the war was felt very acutely. In addition to single-house and large-apartment projects, a number of federal office buildings, for both temporary and premanent use, were constructed in the area. The new Naval Medical Center at Bethesda was completed in 1942 and has since been enlarged. In one area near the extreme end of the district, nearly two miles from any of the then existing facilities, two large, permanent federal office buildings, housing nearly 6,000 employees, and several large groups of federal housing and private apartment projects were erected. Water and sewer service had to be made available to these. In a short time there will be more than 10,000 people residing in this section.

A rapid, although nothing approaching what has been experienced, development of the district had been anticipated during the years succeeding 1938, and plans had been worked out for a project for increased water supply to double the capacity of existing works. This work was intended to start in 1941, so that the district could have the benefit of the additional water in 1943. It was believed that the distribution system was reasonably free from leaks and that most of the water pumped could be accounted for; but

A paper presented on October 16, 1943, at the Four States Section Meeting, Philadelphia, Pa., by Harry R. Hall, Chief Engr., Washington Suburban Sanitary District, Hyattsville, Md.

in the face of a certain, immediate and large increase in consumption before the increased water supply project could be made available, it was felt that a thorough leakage survey of the entire system might disclose unknown leaks. By this means additional water could be recovered to relieve the shortage.

Accordingly, The Pitometer Co. was engaged early in 1941 to make this survey. The final result showed that leakage in the system amounted to some 500,000 gpd., 91.5 per cent of the water actually was sold through meters and only 3.5 per cent was unaccounted for, out of an average consumption of 8 mgd.—not a very fruitful possibility for saving much water. However, through a number of connections to the Washington system (intended for emergency use) it had been possible to secure enough water in past years to take care of peak requirements in the summer. It was hoped that Washington, which was also undergoing the same rapid development and also furnished all the water for Arlington County, Virginia—another fast-growing section of the metropolitan area across the Potomac River—could spare enough to carry this district over the peaks until the new supply could be completed.

Then came Pearl Harbor. Before that time work had been started on the dam on the Patuxent River to impound 6½ bil.gal. of water. The contract already had been let for a new 10-mgd. filter plant and, following shortly thereafter, for a 10-mi., 30-in. and 36-in. force main and supply line to the distribution system. Plans for a new raw water pumping station were nearly completed. It was possible to secure most of the materials for the dam on which work was continued, although at a very much reduced rate of progress due to labor conditions. It was completed to such a point in July 1942, however, that water could be stored behind it. It is now finished, except for crest gates that cannot be installed until after the war, and the amount of water that can be impounded will be ample for several years.

The filter plant, pumping station and supply line, however, were not constructed because of the growing shortage of critical materials, and for many months the possibility of building them during the war was remote, despite the increasingly serious situation that was developing on the water supply. Finally, however, after the lapse of more than a year, clearance was given by the War Production Board in February 1943. All are now under construction and every effort is being directed towards having them in operation by spring or early summer in 1944—a year later than originally anticipated.

The Washington Suburban Sanitary District is peculiar to itself as regards fluctuations in rates of consumption. It is a suburb of Washington and almost entirely residential. It has no large industries and consequently there is no decrease in industrial demand during the night hours to compensate for the sprinkling load of early evening in hot, dry weather. This results in very high-peak consumption figures; daily rates of twice, and hourly rates of nearly four times, the average rate have been experienced. It may readily be seen what such a varying demand can mean to a system with a filter plant of 10-mgd. nominal capacity where the average consumption now exceeds 10 mgd. The average for 1943 has been 10.4 mgd.—an increase of 25 per cent in the past two years. This

was the situation at the beginning of what proved to be one of the hottest and driest summers ever experienced.

In 1942, when the consumption was around 9 mgd., the district became alarmed at the possibility of its not being able to meet even a reasonable summer increase in demand and, as a result of some very hot weather late in May, had prepared notices to consumers imposing rigid restrictions during the ensuing summer months. These notices had been given to the newspapers for publication. However, frequent rains came shortly after, the newspaper notices were withdrawn and just as it seemed the consumption was about to reach another high figure, more rains followed. This condition continued throughout the entire summer, thus eliminating entirely the necessity of any restrictions.

Patuxent River

The consumption rate fluctuates with sunshine and rain. Even a cloud in the sky will cause a marked decrease and a rain, no matter how slight, will bring the rate back to normal almost immediately. It may be seen, therefore, what an important part the sprinkling of lawns and other water requirements of the summer season play in the operation of a system such as this one. It was definitely apparent, in the beginning of the summer of 1943, that a 100 per cent overload could not be met even with full availability of all the water that could be drawn through the Washington connections. There was plenty of raw water in the new Patuxent River reservoir to supply any demand to be expected, but the new filter plant, pumping station and supply line of the increased water supply project were nearly a year from completion, so the raw water could be used only to the extent of the capacity of existing purification and pumping works. The distribution system was in good condition, so no additional water could be secured by looking for leaks. The only way to meet the increased demand was to restrict sprinkling and all other uses of water except for essential purposes.

Enforcement Procedure

The district does not possess the advantages of the municipality in controlling the improper use of the water system by the public, for it operates in parts of two counties and the commission has no control over any police force. Any enforcement of rigid restrictions on the use of water, therefore, would have to be secured by the voluntary services rendered by county and local police. While there was no reason to believe the fullest cooperation would not have been secured from these numerous police units, the commission felt that in this critical period people were becoming accustomed to making sacrifices and that an appeal for their help in reducing water consumption, by refraining from the usual unrestricted sprinkling, would be successful. It was felt also that less ill-will would be incurred than by attempting to pass a rigid regulation banning the use of water for such purposes and threatening dire penalties.

The campaign was started in May by news items in the Washington and local newspapers. The response to the appeal was gradual, but the effect was noticeable in that the high peaks of other summers were not reached. It was apparent that many people had put away their hoses. The word travelled from person to person; people who had not seen the newspaper notices, in many cases, were informed about them

by their neighbors. During the early part of the campaign, however, a slight leak developed in one of the conduits in the Washington Aqueduct and the authorities felt it advisable to shut down the conduit and make the repair immediately. As a precaution, restrictions were placed on the use of water in Washington until completion of the repair. It was only of a week's duration, but immediately upon the announcement by the Washington authorities that the restrictions in Washington had been lifted, many consumers in this area, who were not familiar with the general water supply situation, assumed that the Washington Suburban Sanitary District likewise was out of trouble and started to sprinkle again.

Public Co-operation

At any rate, it was necessary to make another start and get more publicity into the city and local papers. The response was generally good. Here and there people were to be seen watering their lawns, but when spoken to agreed to cease the practice. Many said they had not read the articles; some thought they were only preliminary warnings and that, if conditions really became serious, formal notices would be issued and they were waiting for them. No concerted effort was made to cover the territory to look for violators. If, as the men from the Washington Suburban Sanitary District driving around in performance of their regular duties, saw a sprinkler they would stop and speak to the householder.

In most cases people assumed a very co-operative attitude and were glad to do their part. Some even seemed chagrined and acted as though they had been guilty of lack of patriotism. The many burned lawns and dying shrubbery gave mute evidence of the splendid and serious effort on the part of most of the people to give their loyal support to efforts to maintain uninterrupted service throughout the system. Of course, here and there was a man who knew his rights and intended to stand upon them. However, such people are to be found everywhere. It makes no difference whether it is water, butter, coffee or gasoline, they will always be in evidence and little can be gained by arguing with them, although they are grossly unfair to their more generous and public-spirited neighbors who comply. Then, there was the type who would have a hose tucked away, hidden behind a shrub and who would allow the water to run silently all night where it couldn't be seen. Not even the police would have apprehended such persons unless, as happened in a few cases, the tell-tale trickle of water ran out on the sidewalk and down the street.

Toward the middle of August it was decided to follow up the newspaper articles by printed notices mailed to all consumers. These concluded with the warning that the commission would be obliged formally to impose restrictions on the use of water which would carry penalties for violations unless there was a general compliance with its appeal. By this time the situation was well under control and nothing further was required to be done. In fact, near the latter part of August it was found possible to ease up slightly on the restrictions by permitting water to be used for watering shrubbery and trees—but not for sprinkling lawns.

The result of this campaign was that, instead of our reaching a possible maximum consumption of 18 or 20 mgd., which was the normal expectancy had the water been available and no restrictions in effect, the greatest single day's use was 15 mil. gal. and the average

high mark was around 12 mgd. The excess above the amount available from our filter plant was drawn from Washington. During all this time the 10-mgd. filter plant operated at a rate of from 12 to 13 mgd. without the slightest effect upon the physical or sanitary quality of the water produced and without any difficulties whatever in its operation.

The experience in dealing with the consumers during this trying period is a real tribute to the splendid spirit of the American people in times of emergency. When they can be shown the real necessity for making sacrifices they are willing to do so, but the emergency has to be real and they have to be convinced. Apparently they were convinced that in this case it was real.

War Production Board

Housing Utilities Standards Amended

WATER utilities facing the necessity of extending service to war housing projects should note that on February 15, 1944, the Housing Utilities Standards were amended. Excerpts from the revised text follow:

These Standards supersede the Housing Utilities Standards and Interpretations issued August 25, 1942. They are to be used by utilities and builders of war housing in the design and construction of on-site and off-site facilities to provide electric, gas and water facilities to housing, as required by Supplementary Utilities Orders U–1–d and U–1–h and such other War Production Board Orders as from time to time may refer to these Standards.

They do not replace the utilities construction standards set out in Schedule I of Supplementary Utilities Order U–1–f. At present they are applicable only where there is construction or remodeling of the dwelling to be served which requires an authorization from the War Production Board to begin construction or remodeling, under Conservation Order L–41.

Standards for Water and Gas Facilities

Maximum Main and Service Allowances

1. The total length of water or gas mains and services to be built to serve single family detached dwelling units in the housing project shall not exceed, respectively, in lineal feet, 150 times the number of such units in the project.

2. The total length of water or gas mains and services to be built to serve any type of dwelling except a single family detached dwelling unit in the housing project shall not exceed, respectively, in lineal feet, 130 times the number of such units in the project.

These main and service allowances shall be reduced by the length of any exterior pipe furnished by the builder.

The Housing Utilities Standards were published by the WPB. in its *War Housing Manual* effective December 12, 1942. Any water works executive having need for a copy of this manual should obtain it from the WPB.

Reducing Water Waste in Industrial Plants

By Lewis B. Miller

THE greatly increased production of civilian and war goods in the factories of this country has been paralleled by a corresponding increase in the use of industrial process water. This tremendous rise in industrial water usage has strained the capacities of the water treatment plants to meet the additional requirement. In the following paragraphs, methods of reducing water consumption in cooling systems and as process waters, methods of heat recovery from process waters, and reduction in water usage by means of surveys of water waste and through educational efforts, are discussed. The consulting organization with which the author is associated has proven, within the last year or two, the effectiveness of the methods discussed.

Cooling Waters

One type of cooling system which is widely used is known as the "once-through" system, in which the cooling water passes once through that part of the system which requires cooling and is then discharged to waste. Obviously, this type of system is wasteful of water. Once-through cooling systems have been widely used in connection with air conditioning, although local legislation in many places now requires the re-use of cooling water in these systems.

In cooling systems it is frequently possible to re-use process waters which would otherwise be discharged to waste. In industry, process water can frequently be re-used as cooling water either without further treatment or, if necessary, after being subjected to treatment which will fit it for re-use.

An unusual instance of the re-use of waste waters is reported in the case in which the Bethlehem Steel Corp. plant at Sparrows Point, Md., purchases up to 40 mgd. of treated sewage from the city of Baltimore for use as process water. The treated sewage is purchased under definite specifications. A similar case is reported for a railroad in Kansas and for an oil refinery in Texas.

Recirculating systems are much more economical of water than is the once-through system. Economy in water usage can, therefore, be effected by replacing once-through systems by recirculating systems.

Cooling water used in a recirculating system is first passed through that portion of the system in which cooling is effected and the heated water is then passed to a spray system, a natural draft tower, a forced draft tower or some other means of cooling the water again. In the spray system or cooling

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tower the water is cooled by its own evaporation. Under these conditions the recirculating water becomes more and more concentrated, with regard to its mineral content, the more often it is recirculated. Hence, blowdown must be used in recirculating systems just as in steam boilers and make-up water must be supplied to replace the loss by evaporation and blowdown.

Most waters used for cooling purposes are not in chemical balance. That is, cooling waters are normally either scale forming or corrosive. This factor is of importance, since with waters used in metallic equipment or pipes, the efficiency of the equipment is affected by the formation of scale and the life of the equipment is reduced by corrosion. By intelligent chemical control, under the supervision of those who are familiar with this subject, cooling water may be so conditioned as to be in substantial chemical balance, thus reducing to a minimum both scale formation and corrosion.

Obviously, scale formation and corrosion will both be accentuated in recirculating systems where concentration of the chemical constituents is effected through evaporation. Not only must the recirculating water be kept in proper chemical balance but the cycles of concentration must be limited. By proper control of the cooling water, chemical balance may be maintained and the cycles of concentration increased with a resultant further saving in make-up water.

In addition to corrosion and scale formation the development of biological growths must be avoided. Bacterial and algal growths which cause the formation of slimes and coatings upon equipment and within pipes, and which resemble scale formation in many respects, may be avoided by appropriate chemical treatment of the cooling water. Where biological growths have been developed these may be eliminated by mechanical cleaning of the system, as far as possible, followed by suitable chemical treatment of the water.

Process Waters

Process waters, instead of being run to waste following their initial use, may frequently be re-used, although often only after suitable mechanical or chemical treatment. Often such treatment is of economic advantage since, during the process of treatment, valuable materials are extracted from the process water.

The paper industry is an example of an industry where very great effort has been made and much money expended in the re-use of process water, or of "white water" as it is termed by the industry. The author who has had extensive experience in this field, uses the paper industry as an example because large sums of money have been spent upon the re-use of white water.

White water is the water which passes over the wire upon which the sheet of paper is formed and which still contains considerable amounts of shorter fibre stock, fillers, colors, etc. By passing the white water to so-called "save-alls" (involving gravity separation or screens) a portion of the paper stock still present in the white water is recovered. The stock thus saved is returned to the paper making system at an economic advantage and the treated white water is frequently reused to a considerable extent by recirculation to the paper machine, as make-up water in the beaters, etc. White water can sometimes be further clarified by chemical means and reused not only as above indicated, but

also on showers, water deckles, etc. The so-called "Adka" save-all and the "Sveen-Pederson" save-all, by a combination of chemical and mechanical treatment, recover a major portion of the stock present in the white water.

Such methods of white water treatment can be used more extensively in some types of paper manufacture than in others. Obviously, where colored papers are being manufactured and where there is frequent change from one color to another, methods of white water treatment are limited and there must always be a certain amount of wastage during the switch from one color to another. The market value of the raw materials used also places an economic limit upon the effort which may be profitably expended in the treatment of white waters.

Progress made by the paper industry in the saving of process water is reflected in the fact that a few years ago it was not an uncommon practice to use in excess of 100,000 gal. of process water per ton of paper produced. Now it is considered good practice to use 20,000 gal. of water per ton of paper. In certain cases where the operation particularly lends itself to the procedure, a substantially closed system may be found in use.

Recovery of Heat From Process Water

In a sense, heat recovery does not come under the title of this paper, since reduction in water usage is not involved. Because of the high specific heat of water, however, heat losses may become very great where quantities of water are wasted. A saving in heat does represent a real economy.

Frequently heat may be recovered through the use of heat exchangers. Another method of effecting heat recovery is to re-use the process water, where this is possible, before complete cooling takes place.

Heat may frequently be saved through the proper use of thermal insulation. This applies to water which is maintained either at an elevated or at a lowered temperature, as through refrigeration. In the use of heat insulation, it is always desirable to obtain the recommendation of a reliable insulation manufacturer before applying such material to any system. Thermal insulation is a highly specialized subject but substantial savings may be made both in the cost of the insulation and in the subsequent heat savings by obtaining an appropriate recommendation from a company which specializes in thermal insulation.

In the use of heat exchangers, the same problems of scale formation, corrosion and biological growths occur. In general, the higher the temperatures involved the more rapidly will scale formation on corrosion occur. It must not be overlooked that many types of bacteria which cause corrosion or which may give rise to slimes are highly heat resistant. Intelligent control of the water, by a qualified and experienced engineer or by operators acting under his supervision, is essential in order to minimize these effects.

Surveys of Water Usage

Very frequently substantial savings in water may be effected, particularly in large industrial concerns, through a survey of water usage. Most companies do not meter the water to individual departments and do not possess a precise breakdown of their water consumption. A careful survey by an experienced engineer will frequently bring to light unnecessary water loss as by leakage or will determine places

of unnecessary water consumption. For a complete investigation and, in some cases, in order to control usage, it may be necessary to install meters at strategic points. A few examples will indicate cases in which a water survey has brought to light wastage of water.

Leakage Stopped

In one case at a certain factory, information about water usage, recognized as being incomplete, could account for only one-third of the water being treated in the water treatment plant. A hasty survey indicated some obvious leakage which was stopped. Meters are now being installed in this factory in order to measure the amount of water used by different departments. The completion of this investigation will undoubtedly show that there is a serious leakage at some points in the piping; that there is unnecessary water consumption in some department or departments in the plant which can be reduced or; that the actual water requirements of certain departments are considerably greater than is estimated at the present time. In any case actual records will replace guess work and it will be definitely known whether a substantial water saving is possible.

In another plant, a pump of fairly large capacity was used to lift water to an elevated storage tank for gravity flow to points of usage. It was estimated that the pump was capable of handling several times the quantity of water normally used. The pump was actuated by a float in the elevated storage tank so as to start and stop as water usage necessitated. The author checked the periods of operation of this pump and to his surprise found that it ran continuously. Further investigation indicated that the float in the elevated tank was stuck and was failing to shut off the pump so that the water elevation in the tank continued to rise until it reached the overflow point, with the result that a major portion of the treated water was overflowing to waste. A few minutes work repaired the float control with a resultant reduction of approximately 70 per cent in water usage at this point.

Another story is told of a newly-built plant in which water consumption appeared excessive. Investigation revealed that at the time the plant was built a fire hose had been used to flush out a sewer which was just completed and being placed in use. Apparently the construction worker who had turned on the hose went away and forgot ever to return and shut it off. This wastage of water had continued for a number of months until the operating personnel had taken over at the plant and had investigated the reason for the high water usage in the plant.

Another example is presented of a case in which alert operating personnel immediately recognized and stopped unnecessary water usage almost at once. In this plant, in which the author was engaged as consultant, a schedule was set up in which the water plant operators reported water consumption through meter readings at 4-hr. intervals. One night the shift operator noted that water usage appeared to be greater than usual and started an investigation. It was found that in remote parts of the plant two faucets had been left running wide open. When these were shut off the water requirements returned to normal. This case illustrates the excellent control which can be maintained by alert operating personnel if a proper operating schedule is set up for them.

Water Saving Through Education

The average citizen of a community is not conscious of the normal wastage of water which occurs nor of methods of conserving it. It is only when these things are pointed out to him and he is requested to co-operate in the conservation of water that he takes steps to do so. The same is true of the average industrialist. He knows his own manufacturing processes and may even be very expert in them, but in general he is not "water conscious" even though his industry uses very large volumes of process water. Each industry has certain water problems which are more or less peculiar to that industry and which can best be handled by the technical men connected with that industry or by specialists on water who are acquainted with the problems of the industry. Many industries which use large amounts of water have technical associations which deal with their specific problems. It is the author's conviction that an active water committee within each of these technical associations can perform a real service by sponsoring an educational program intended to acquaint the membership of the industry with its specific water problems and devoted to intelligent usage of water.

The Technical Association of the Pulp and Paper Industry is an example of such an association where a great deal of thought and effort has been given to the dissemination of appropriate information upon water. (The author has made reference to water usage in the pulp industry and to the activities of its technical association repeatedly in the present discussion because of personal experience in this industry and because, as Chairman of the Water Committee of T.A.P.P.I., he has followed activities in this field rather closely.)

In the last few years the Water Committee of T.A.P.P.I. has prepared a monograph entitled *Process Water for the Pulp, Paper and Paperboard Industries,* which represents an attempt to present to the pulp and paper industry information on water treatment and usage which is accurate and up-to-date. The monograph is written in simple, non-technical style which can be understood by the non-technical man who may not be familiar with the technology of water. The fact that almost three thousand copies of this monograph have been distributed since February 1942, when it made its appearance, is ample proof that there is a real interest among pulp and paper people in this subject. At each annual meeting of the association a water program is sponsored at which several papers dealing with water problems of the industry are presented. Surveys are made through the industry by means of questionnaires which serve as a basis for the preparation of standards of water quality, measurement and usage, and which are incorporated in the book of standards of the T.A.P.P.I. for the use of its members. The Water Committee also investigates and reports upon specific water problems of the industry. It is believed that this educational program which is sponsored by T.A.P.P.I. is leading to the conservation of water and its more intelligent use by the pulp and paper industry.

Water-Borne Outbreak in an Oregon Shipyard

By Roy E. Dodson, Jr. and A. J. Farrell

ON October 25, 1943, the Oregon State Board of Health was notified that one of the smaller shipyards in the state was experiencing an abnormal number of cases of gastro-enteritis among its workers. It was reported that the number of cases calling at the yard dispensaries for emergency treatment had been increasing for three days, with a peak being reached on October 25. Staff members of the State Board of Health immediately launched a dual investigation of the cases and of the possible sources of infection.

Epidemiological Findings

A comprehensive epidemiological survey of the outbreak was conducted by Dr. Thomas F. Mancuso, Director of the Division of Industrial Hygiene, Oregon State Board of Health. When completed, this survey disclosed that in a period of about two weeks, from October 22 to November 2, there were 1,179 medical visits to the yard dispensaries for treatment of abdominal cramps, vomiting and diarrhea. From this group, 507 individual case histories were obtained and studied. No definitely diagnosed cases of typhoid or paratyphoid fever were reported.

During the two-week period mentioned above, the absentee rate in the yard ran from 10 to 15 per cent each day, as compared with a normal average for the yard of 7 per cent. From these figures, and from the number of cases which were personally interviewed, but which had never reported to a dispensary or had never given case histories, it may be assumed that at least 2,000 employees of the yard were affected. The total number employed in the yard was somewhat less than 15,000.

Inquiry was made concerning the various vehicles of such mass infection, including the yard milk supply, prepared box lunches, prepared hot meals, soft drinks, common drinking fountains and the yard water supply. As soon as sufficient data had been collected from the case histories, it became evident that all of the possible vehicles could be eliminated except the water supply.

Sources and Quality of Water Supply

The only source of water supply was a municipal system adjacent to the yard. River water was formerly used in the cooling and sanitary flushing systems at the plant, but the only line from the river was disconnected and *the river pump dismantled* some years

A contribution by Roy E. Dodson, Jr., Assoc. State San. Engr., and A. J. Farrell, State Plumbing Inspector, Oregon State Board of Health, Portland, Ore.

ago. There were no wells, auxiliary fire supplies or other water sources in evidence on the premises.

During the period in question, routine daily samples from the city distribution system indicated that the water was of satisfactory quality. The same was true of samples from the reservoir serving the area which included the shipyard. The city water supply was further vindicated by the absence of water-borne intestinal upsets in the city generally.

Consideration was given the possibility of a serious local cross-connection outside of the plant but on the same or an adjacent city main. This possibility was discounted when it was found that none of the neighboring industrial or other establishments served by the same mains had experienced any abnormal incidence of intestinal upsets among their personnel. The investigation thus limited itself to the water system within the yard.

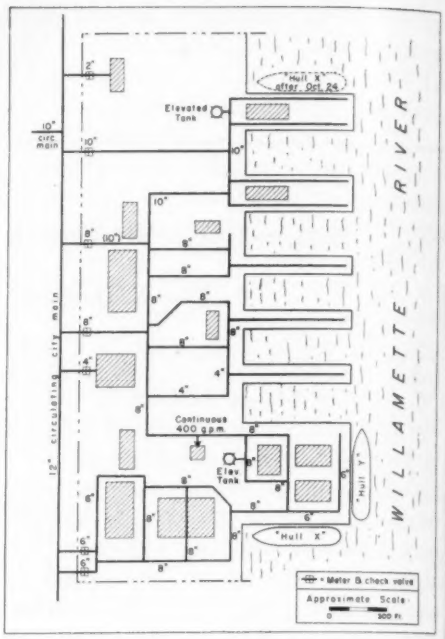


FIG. 1. Schematic Diagram of Yard Distribution System

Water System Within the Yard

The yard was served from a 12-in. circulating city main extending along the entire frontage of the plant. Seven services entered the yard from the main: two 10-in. (one with an 8-in. meter), one 8-in., two 6-in., one 4-in., and one 2-in. All services were metered and *equipped with check valves at the meters.* The 2-in. and 4-in. services each supplied individual buildings, while all of the other services entered the general distribution system extending throughout the yard.

The yard distribution system consisted of four circulating loops at one end, three loops in the central area, and a series of dead-ended laterals at the other end, with these systems connected by an 8 to 10-in. main extending nearly the length of the yard. Lines feeding from the loops and laterals served the various docks, shipbuilding ways, shop buildings and offices. The metered services from the city main entered the system in such a way that it was completely flexible hydraulically (Fig. 1).

Local storage consisted of two elevated steel tanks, one connected to the loop systems and the other to the main at the opposite end of the yard. Both tanks were of 100,000-gal. capacity and both were controlled by check valves which did not permit the tanks to discharge unless the distribution system pressure fell below about 45 psi. The tanks were filled through manually-controlled filler pipes. Both tanks were full at the time of the investigation and there was no evidence that either tank had been drawn upon or filled for many months.

The average water consumption within the plant was in excess of 600,000 gpd. Much of this consumption was accounted for at one constant point of use—the cooling system in the central compressor building. This unit used about 400 gpm. at all times during all shifts, or over 500,000 gpd.

Distribution system pressures within the yard normally varied from 40 to 75 psi. and seldom, if ever, exceeded 80 psi.

Possible Sources of Contamination

The shipyard is located on the bank of the Willamette River which carries raw sewage from a total contributing population of over 400,000. This sewage is introduced from some 17 cities and towns over a stretch of river more than 150 mi. in length. By the time it passes this shipyard, the river is affected by the tides and, under fairly common conditions of high tide and medium or low river flow, the current may cease or may even reverse itself.

In addition to the tremendous sewage load in the river from farther upstream, a 60-in. domestic sewer entered only 500 ft. above the upstream end of the shipyard. Under normal conditions, sewage from this outfall undoubtedly would tend to cling to the bank, making the pollution heavily concentrated along the water front of the shipyard. There were also several small plant sewers discharging into the river as it passed the yard, including a 15-in. sanitary sewer at the immediate upstream end of the conversion dock.

Because of the known pollution of the Willamette River, suspicion immediately centered on facilities adjoining it. These facilities included a conversion dock, shipbuilding ways, and several outfitting docks and basins. A general investigation of the area on October 25 and 26 failed to reveal any possible source of such serious contamination of the water system. There were in evidence no fire pumps or other auxiliary equipment which could be connected with the river or with any known sewers. Although the plumbing fixtures were not entirely protected against back-siphonage, no traces could be found of conditions which would have allowed this to occur, at least on such an extensive scale.

Investigation of River-Front Facilities

Early in the investigation it became apparent that an abnormal number of the cases reporting to the dispensaries were employed on the conversion dock or on "Hull Y," a vessel berthed at the conversion dock. Suspicion, therefore, centered on this particular area, but nothing was found on "Hull Y" or on the conversion dock which would explain the contamination, nor was there any record of piping changes having been made in the area within recent weeks. It soon became evident that some tremendous vehicle of contamination had existed in the vicinity of the conversion dock during the week preceding October 25, but that it had been either altered, hidden or removed entirely by October 25.

It was then found that a nearly completed vessel, "Hull X," had been berthed at the conversion dock for several weeks but had been moved downstream to a final outfitting dock *on October 24*. As this was such a suggestive clue, all further effort was centered on "Hull X."

Investigation of "Hull X"

This vessel was nearing completion, with all essential machinery and piping

already installed. Dock trials had been held on October 10, after which the vessel was placed in dry dock for inspection. On October 13 it was returned to the conversion dock where it remained until October 24.

After the dock trials, the steam plant which would normally operate all engines and pumps aboard "Hull X" had been shut down. To supply electricity aboard, two diesel-operated auxiliary generators were in constant operation after the vessel returned from dry dock. *To supply fire protection aboard, one of two electrically-operated auxiliary fire pumps was also in constant operation during this period.*

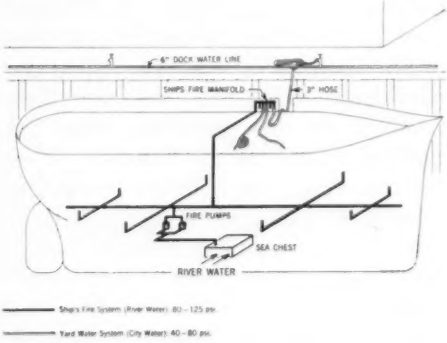

6" DOCK WATER LINE
SHIPS FIRE MANIFOLD
3" HOSE
FIRE PUMPS
SEA CHEST
RIVER WATER
Ship's Fire System (River Water): 80 – 125 psi.
Yard Water System (City Water): 40 – 80 psi.

FIG. 2. Diagram of the Cross-Connection Aboard Hull "X"

The fire system on "Hull X" was intended to operate at a pressure of about 100 psi., using steam-driven turbine pumps drawing from "sea chests." *While at the conversion dock, the auxiliary electric pump was being operated at from 80 to 100 psi., with test runs reaching 125 psi. or higher. This pump also drew water from a "sea chest" (i.e., in this case, river water)* (Fig. 2).

It was found that the fire system on "Hull X" radiated from a 12-in. main which extended throughout the length of the ship, two decks below the main deck. The usual sprinkler systems and fire hydrants were supplied from this main. Of particular interest in this investigation was a series of branch lines extending upwards to the main deck and terminating at the sides of the ship. These branch lines were for the sole purpose of serving fire manifolds located along either side of the main deck. The valves controlling these branch lines were directly off the 12-in. fire main, *two decks below the manifolds themselves. When these valves were open, salt water (or river water) was available at the main deck manifolds under a pressure as high as 125 psi.*

After "Hull X" had undergone its dock trials, the fresh-water circulating system was not placed in operation. Therefore, in order to have fresh water under pressure for testing various pieces of cooking equipment, etc., a 3-in. hose was brought aboard from a dock hydrant supplying city water. As this fresh water might have been required at two or three places on the vessel at one time, it was desired to run two or three small hoses from the 3-in. supply hose. Instead of using a portable header or multiple connection between the hoses, *the 3-in. dock hose was attached to one of the fire manifolds described above*, and the small service hoses were then run by means of adapters from this manifold to the points of use. In other words, a permanent fire manifold on the main deck of "Hull X" was used, merely for convenience, to distribute city water aboard instead of using a portable manifold or other independent connecting device.

This cross-connection existed aboard "Hull X" during practically the entire period from October 13 to October 24,

according to men working on the vessel. That such a hazardous connection would have been made and left for this period seemed hardly believable, yet when "Hull X" was inspected at the final outfitting dock on October 26 *the same connection had again been made, and was observed by the investigators.*

The pipe fitters working on "Hull X" were vaguely aware of a hazard in this connection, but they evidently assumed that as long as the valve controlling the manifold branch was closed, the hazard was not worthy of consideration. Yet there were no warning signs or instructions, nor was the control valve locked in a closed position. Any person unfamiliar with the piping arrangement could have opened the valve and left it open for any period of time. This evidently occurred, and river water was automatically pumped into the yard distribution system through the 3-in. dock hose, with no immediate means of detection. The normal pressure differential would easily allow this to occur.

The exact time or times of the contamination and the total length of time it existed were not determined. It was assumed, however, that the cross-connection was open for a considerable period of time, as contaminated water was found at points in the yard well removed from the conversion dock. It is quite possible that the cross-connection was opened again at the final outfitting dock, as indications of contamination were also found in that extreme end of the distribution system.

The person responsible for opening the control valve, thereby allowing the contamination to take place, was not found. This was considered to be a relatively unimportant point, as it was felt that the real responsibility rested upon those who permitted such a connection to be made in the first place.

Corrective Measures

Of 28 water samples taken at various points in the yard distribution system on October 25, the first day of the investigation, 3 were positive for coliform organisms. Because of the intricate hydraulic pattern of the system, thorough flushing was selected by the yard management as a quicker and easier method of eliminating this contamination than chlorination. However, the first flushing by the yard maintenance staff was completely ineffective, as the next series of water samples taken on October 28 showed 6 positive out of 8 samples collected. A third series showed 10 positive out of 21 samples collected. After a thorough flushing, during which each branch of the system was isolated, another series of samples was taken. Of 21 samples in this last series, only 3 showed even slight contamination.

In view of later events, it is evident that the entire shipyard should have been closed down at once and the distribution system heavily chlorinated. However, there was considerable feeling against such procedure among the yard executives, especially as time was so important to them in their production schedule. Inasmuch as the yard was a private concern and the city mains were protected by check valves, the issue was not forced.

The cross-connection aboard "Hull X" was removed and measures were taken by the management to prevent a similar occurrence on any of the other vessels in the yard.

Recommendations

1. Pipelines or hoses carrying potable water should never, *under any cir-*

cumstances, be physically connected to any piping system carrying non-potable water. This rule should be followed at all stages of construction on vessels and elsewhere. Check valves and backflow prevention devices are not recognized in Oregon as furnishing complete protection; therefore, *no actual or potential physical connections are allowed.* This policy is set forth in the State Statutes, in

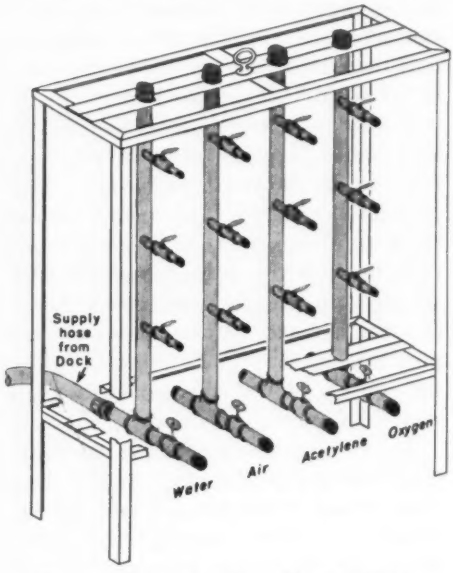


FIG. 3. Suggested Portable Manifold

regulations of the State Board of Health, and in the present instances in an ordinance of the city involved. The latter ordinance provides for the *immediate discontinuance of city water service* upon the finding of any physical cross-connection with a non-potable supply.

2. If fire protection is to be maintained aboard ship when the ship's regular fire pumps are down, an auxiliary fire pump may be provided to maintain fire pressure, using sea water or river water.

3. If potable water must be carried aboard ship under pressure, for any use but the filling of the ship's fresh water system, temporary manifolds or multiple hose connections should be used to distribute the water. These should be placed and removed with the supply hose. A suggested form of portable manifold for the distribution of water, compressed air, oxygen and acetylene is shown in Fig. 3. This device is used with good success in one of the larger Oregon shipyards and while it may be more adaptable to "mass production" yards, it should be of use at any shipyard, ship repair plant or dock. The same plan would often suffice for fire protection.

4. Whenever a ship's fire pumps are in operating condition, some qualified person on each shift should be made strictly responsible to see that absolutely no cross-connections are made. This should be mandatory wherever ships are being built, re-built or repaired.

Anthrafilt and Its Significance

By H. G. Turner

ANTHRAFILT is a filter medium made from Pennsylvania anthracite. The first step in its preparation is the selection of a type of raw material which will provide a particle free from small fracture cracks and possessing the best form. This particle must be strong enough to withstand years of backwashing without breaking into smaller grains and should be sharp, angular and flat.

After the highest quality of raw coal is selected it is sent to the breaker where it is crushed, thoroughly washed and cleaned by gravity separation methods which free it from slate and associated, non-coal mineral substances. The crushed material is finally screened over vibrating screens equipped with jets of water which assist in producing the desired size and remove, as far as possible, all very fine particles.

No one standard size is made in the screening process. Instead, different sizes are made to meet the various conditions of water treatment, water characteristics, filter design and filter operation. Information as to the best size for a given installation is obtained through a questionnaire sent to each purchaser. The purchaser who has had no experience with Anthrafilt, should accept the specifications of the manufacturer regarding the proper size to be used. The manufacturer can make one size as cheaply as another so has no reason, other than the satisfactory operation of filters, to recommend one size in preference to any other. No filter expert, regardless of his years of experience or standing in the profession, can say with assurance what size Anthrafilt should be used in a filter unless he has conducted his own tests on this material under proper conditions in the laboratory or in the field. The reason for this will be made clear as this thesis is developed. These remarks all apply to the sand-size Anthrafilt. The sizes that are used in place of gravel are made to standard dimensions and are used in much the same way as gravel.

Properties of Anthrafilt Versus Sand

Sand is composed almost entirely of silica. It is insoluble in most acids but is soluble in alkalies. Its specific gravity is 2.65, and weight approximately 100 lb. per cu.ft. The particle shape is commonly rounded.

Anthrafilt is composed of carbon plus a small percentage of ash-forming mineral matter. It is not soluble in common acids or alkalies. Its specific gravity is 1.60 and weight approxi-

A paper presented on November 19, 1943, at the Florida Section Meeting, Ft. Lauderdale, Fla., by H. G. Turner, Research Engr., Anthracite Equipment Corp., New York, N.Y.

mately 50 lb. per cu.ft. The particle shape is sharp, angular and flat.

While it is true that silica sand and Anthrafilt have many other characteristics than those given, these are the ones of greatest significance in their contrasting behavior in filters.

Filters act both as strainers and as entrapping agents. Where no coagulant is used, the strainer action predominates. Where coagulants are used, entrapment predominates. Since the degree of entrapment is directly proportional to the surface area of the filter medium, the angular particle of Anthrafilt is more efficient than the same sized sand having a spherical shape, because an angular grain has a greater surface than a sphere of the same volume.

In practice, this means that a coarse Anthrafilt particle will give the same degree of turbidity removal as a relatively fine sand. This is important when one considers that a coarse filter medium, in contrast to a fine one, will give longer runs between backwash periods, will not clog as readily with algae, will develop lower head loss, will permit higher rates and will be cleaned more thoroughly when backwashed.

Since coarse Anthrafilt ($\pm$ 0.75 mm. effective size) is as efficient as fine sand ($\pm$ 0.40 mm. effective size) in turbid matter removal and since it weighs half as much, it can be substituted for fine sand without sacrificing the quality of effluent and without detracting from a high degree of filter bed expansion when backwashed with the same velocity as used with fine sand.

Users of Anthrafilt have found that it is more readily cleaned under routine backwashing. This has been strikingly demonstrated by Paul Weir of Atlanta, Ga., who made intensive turbidity determinations on the wash water discharged to sewer in the case of parallel experimental sand and Anthrafilt filters. In every determination the turbidity of the waste water from the Anthrafilt filter was higher than it was in the sand unit. This behavior is partly due to the particle shape and partly due to the composition of the Anthrafilt grains. Because of its dominant carbon content, Anthrafilt does not react chemically with the turbid matter which envelops the grain during filtration. Hence, it not only releases common dirt easily but also does not become badly coated with lime, manganese or iron. With proper filter design and operation it will not coat even where lime-soda softening is used and only very slightly in iron removal filters.

Where the hot-process, lime-soda softening is used, Anthrafilt (1), after the first few days of operation, will contribute no silica or other mineral matter to boiler feed water. Sand, on the other hand, will release silica to the water flowing through the softening unit.

The properties of Anthrafilt have made it very effective in filters of all kinds—filters for removal of oil, boiler treatment filters, swimming pool filters, chemical filters, iron removal filters, sewage filters, portable filters where light weight is important, and municipal filters of gravity, pressure or slow-sand type.

Increase in Filter Capacity

The first filter for clarification of municipal water was a slow sand filter built in London, England, in 1829. This filter was cleaned by scraping the surface and removing the upper portion of the sand for washing. In 1856, Tours, France, built the first filter to be backwashed. Since it was impos-

sible to obtain enough pressure to lift the sand, this system of cleaning was abandoned.

The rapid filter was an American invention which was installed in industrial plants around 1883. This type of filter was first employed in the treatment of a public water supply at Somerville, N.J., in 1885. Up to this time little attention had been given to coagulation. From 1885 on, the use of coagulants became a widespread practice. Sedimentation basins were given no serious consideration until several years after coagulation came into the picture. In all early filters the efficiency of the units was rated on bacterial removal. Chlorination had not yet become a recognized practice. Sand sizes, filter depths and filtration rates were all designed to give a clear water under these crude conditions of water treatment and filter design.

Historical Data

This historical sketch is cited to show that we may have inherited rules and regulations which no longer apply in view of filter improvements in many directions. The most outstanding relic of those early days is the commonly accepted filtration rate of 2 gpm. per sq.ft. for rapid filters. There have been great improvements in sedimentation basins, coagulation, chlorination and filter design, and yet the presently accepted filtration rate is the same as it was in the days before coagulation, chlorination or sedimentation. This does not seem logical.

There is adequate evidence that a filtration rate considerably in excess of 2 gpm. per sq.ft. is possible. As far back as 1898, Fuller reported successful filter operation at rates as high as 3 gal. In his *Report on Investigations Into the Purification of the Ohio River Water at Louisville, Ky.*, he states: "But it is probable, in view of the results of the Western pressure filter, that in practice under favorable conditions the plant could be operated so as to make increased (uniform) rates in a measure meet increased demands for filtered water." In the same report he states further: "In all these systems the provision for subsidence, both with and without coagulation, was thoroughly inadequate."

As an example of more recent evidence, it has been reported that a total 4-gal. rate is used through sub-surface as well as surface filtration at the Kenilworth, Ill., filter plant (2). While the rate is 2 gal. through the top of the filter and an added 2-gal. sidewise rate below the upper 2 in., the total vertical rate for the lower half of the filter is 4 gpm. per sq.ft.

About 1940, the Lansing filtration plant (3) was operating at a 3-gal. rate. The St. Louis (Howard Bend) plant is also designed to operate at a 3-gal. rate. The most recent installation is the new Chicago Filtration Plant (4) designed to operate at a 4-gal rate during the summer and a 3-gal. rate during the winter. In addition, many plants are operating more or less sub rosa at a 3-gal. rate.

In all the recent filtration plants designed to operate at higher than a 2-gal. rate, flocculators are used and some form of agitation or surface wash is used in the filters. Furthermore, at these plants more than average attention is given to the formation of a large, or at least a tough, floc particle.

The Part Played by Anthrafilt in Increasing Filter Capacity

The first municipal filtration plant to increase its capacity through the use of Anthrafilt was the Passaic Valley Wa-

ter Commission plant at Little Falls, N.J. (5). Figure 1 shows how the capacity of these filters was increased at least 50 per cent. The solid lines indicating the filtration rate show that Anthrafilt in tank No. 14 maintains its rate with little change over the full length of run while in the sand tanks Nos. 1 and 17 the flow drops off rapidly within 2 to 4 hr. Air wash was used in these filters. The next municipal plant to use Anthrafilt to increase plant capacity was New Toronto, Canada, where capacity has been increased 100 per cent. At about this time, the plant capacity of Oklahoma City, Okla., was increased from 16 mgd. to 30 mgd. by substituting Anthrafilt for sand.

Within the last year the Pennsylvania Water Co. at Wilkinsburg, Pa., because of excessive war demands, was

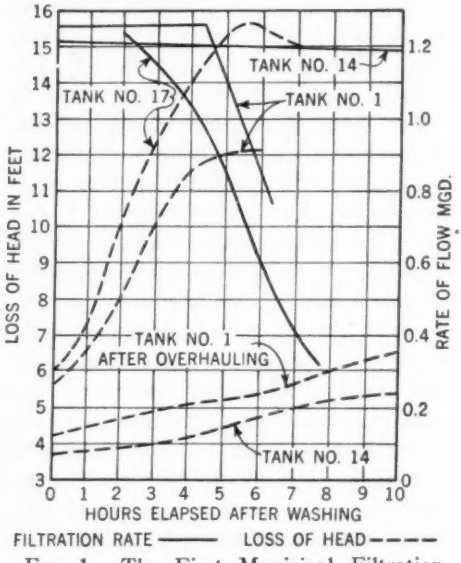


FIG. 1. The First Municipal Filtration Plant (Passaic Valley, N.J.) to Use Anthrafilt to Boost Its Filter Capacity Showed a 50-Per Cent Increase.*

*Courtesy Arthur T. Cook, Gen. Supt. and Engr., Passaic Valley Water Com., Paterson, N.J.

forced to increase its capacity (Figs. 2 and 3). It will be noted that better than a 3-gal. rate is maintained for 24 hr. by the Anthrafilt units but it decreases rapidly in the sand units. With the filters not greatly loaded (Fig. 4) both Anthrafilt and sand hold their higher rates for the duration of the run although the Anthrafilt develops a much lower head loss. Palmer Filter Agitators were used.

Figures 5 to 8 are photographs of 7-day loss-of-head charts from the filters of the city of Buffalo, N.Y. It will be noted that the Anthrafilt filter (Fig. 5) shows a filter wash once during the week; the sand filter (Fig. 6) shows two washes during the week. In Fig. 7, the Anthrafilt filter had to be backwashed twice a week during the algae season while the sand filter (Fig. 8) had to be washed 14 times. Palmer Filter Agitators were used in the Anthrafilt filter.

Many industrial plants have increased their filter capacity through the use of Anthrafilt plus recommended mechanical alterations. The best example of what has been done in an industrial plant is the experience of the Hammermill Paper Co. at Erie, Pa. A few years ago they doubled the capacity of their filters by changing from sand to Anthrafilt and installing Palmer Filter Agitators. This industrial plant is chosen because they filter 25 mgd. as compared with 30 mgd. for the entire city of Erie (population 127,000) and because they make a product of such high quality that their water must be close to perfect.

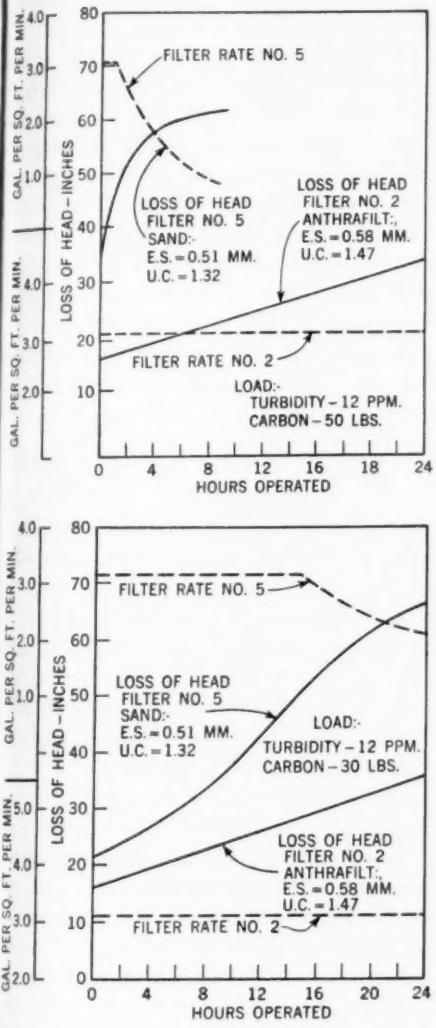
The author is firmly convinced that any filtration plant that is now operating at a rate of 2 gpm. per sq.ft. can increase its capacity by 50 to 100 per cent by taking one or all of the following steps:

1. Conduct laboratory tests to determine what kinds and what amounts of chemicals are necessary to secure the best floc under all conditions.

2. Make provision for quick mixing of chemicals with raw water.

3. Use pre-chlorination.

4. Improve flocculation by installing flocculators.


FILTER RATE NO. 5
LOSS OF HEAD FILTER NO. 5 SAND:- E.S. = 0.51 MM. U.C. = 1.32
LOSS OF HEAD FILTER NO. 2 ANTHRAFILT:- E.S. = 0.58 MM. U.C. = 1.47
FILTER RATE NO. 2
LOAD:- TURBIDITY – 12 PPM. CARBON – 50 LBS.
LOSS OF HEAD – INCHES
GAL. PER SQ. FT. PER MIN.
HOURS OPERATED
FILTER RATE NO. 5
LOSS OF HEAD FILTER NO. 5 SAND:- E.S. = 0.51 MM. U.C. = 1.32
LOAD:- TURBIDITY – 12 PPM. CARBON – 30 LBS.
LOSS OF HEAD FILTER NO. 2 ANTHRAFILT:- E.S. = 0.58 MM. U.C. = 1.47
FILTER RATE NO. 2
LOSS OF HEAD – INCHES
GAL. PER SQ. FT. PER MIN.
HOURS OPERATED

FIGS. 2–3. Better Than a 3-Gal. Rate is Maintained for 24 Hr. by Anthrafilt Units at Wilkinsburg, Pa.†

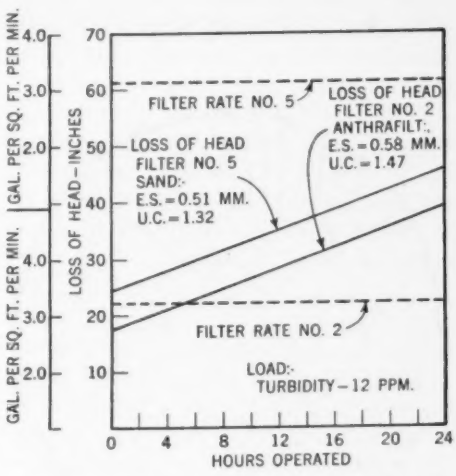

FILTER RATE NO. 5
LOSS OF HEAD FILTER NO. 2 ANTHRAFILT:- E.S. = 0.58 MM. U.C. = 1.47
LOSS OF HEAD FILTER NO. 5 SAND:- E.S. = 0.51 MM. U.C. = 1.32
FILTER RATE NO. 2
LOAD:- TURBIDITY – 12 PPM.
LOSS OF HEAD – INCHES
GAL. PER SQ. FT. PER MIN.
HOURS OPERATED

FIG. 4. Filters Are Not Heavily Loaded; Both Anthrafilt and Sand Hold Higher Rates for Duration of Run at the Wilkinsburg Plant.†

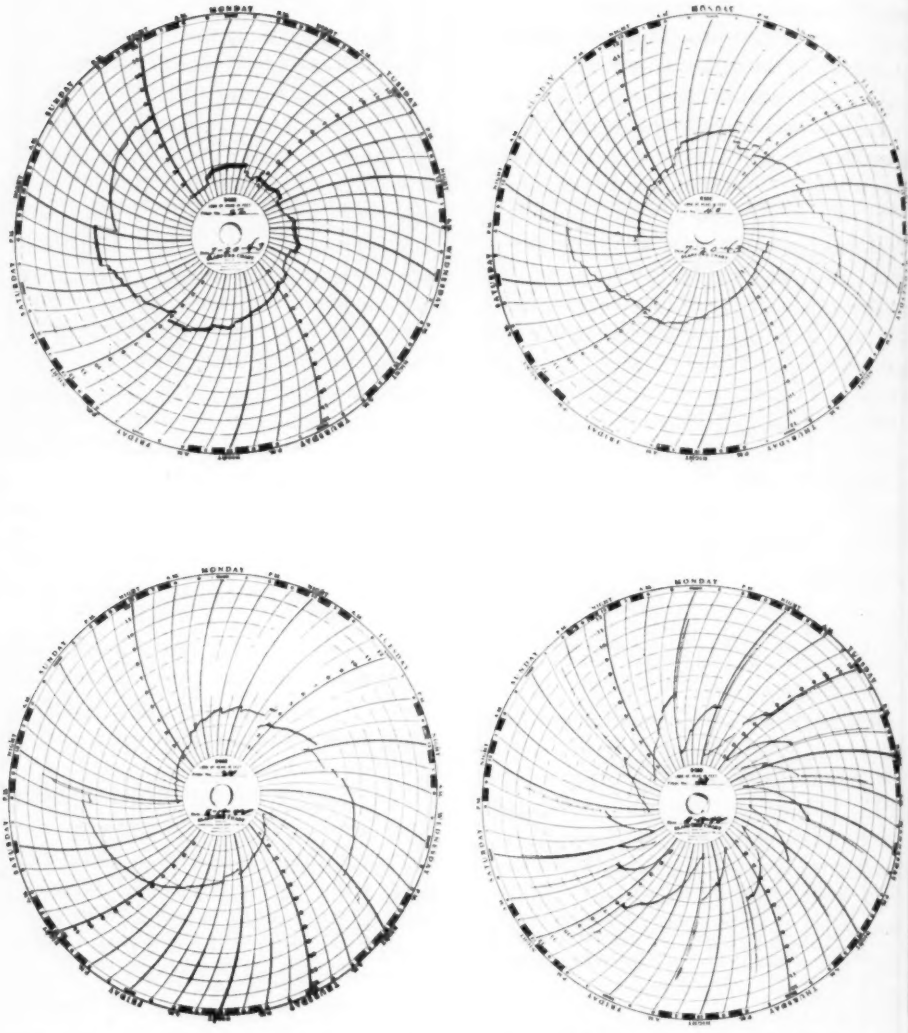
5. By means of floats or color solutions, test basin to locate short circuits. Install or remove baffles to counteract short circuits.

6. Compensate for reduction in sedimentation time and hence overloaded filters by installing surface wash if other forms of adequate sand surface agitation are absent.

7. Change from fine sand to coarse Anthrafilt of the proper size to meet the conditions. Coarse, water-worn sand will not be effective. Crushing vein quartz might work but it would require twice the wash-water velocity for backwashing.

In general, filter runs between washes should continue as long as a satisfactory effluent is produced but not beyond a period where the filter can be cleaned by backwashing. Anthrafilt will give filter runs at least twice as long as sand and still not load the filter to a point where it cannot be cleaned

† Courtesy R. B. Adams, Chief Chemist, Pennsylvania Water Co., Wilkinsburg, Pa.



FIGS. 5–8. Charts Show 7-Day Loss-of-Head From the Filters of the City of Buffalo, N.Y. (Courtesy Henry Wagner, Chief Chemist, Div. of Water, Buffalo, N.Y.)

by backwashing. Georgia (6) obtained experimental runs of 300 hr. in an Anthrafilt unit at the Cornell University filtration plant. He says, however, that ". . . it is not believed to be good practice to put this much load on the filter. Runs have now been reduced to one week and they may be cut even more if future operation makes this seem desirable." There are probably many filtration plant superintendents who would not complain if their filter runs were reduced to one week.

Loss of head is a convenient indicator that a filter has run long enough. It should be correlated, however, with the quality of the effluent and conditions of filter, and should not be used as an arbitrary figure. The loss of head in Anthrafilt is rarely over 4 to 5 ft., whereas sand filters, under the same conditions other than filter medium size, will show a head loss of 9 ft. or more.

Size of Filter Medium and Filter Depth

One of the best papers on this subject was prepared by Thomas M. Riddick (7). Much of the value of his paper is found in a discussion by several experts. In the same Journal is a paper by G. B. McCall, S. E. Edwards, and Edward S. Hopkins (8). After reading these papers, one can arrive at as many different conclusions as a handful of citizens interpreting a paragraph in a standard government order. One thing on which the authors agree is the importance of proper conditioning (9) of water for filtration. This is important because the selection of sand or Anthrafilt sizes and depths, to meet the worst condition during the year, may impose expensive operation costs for 350 days of that year.

Another cause for confusion in such discussions is an attempt to apply small laboratory filter results to actual large filters or to apply findings from a filter of one type to one of different design. If these results are related to a large filter using high-velocity wash and high freeboard, they will not apply to a filter without troughs or low freeboard or to low-velocity wash plus agitation during washing.

In our own experimental work with Anthrafilt and sand it was found that a flat, angular grain was more effective in turbidity removal than a rounded grain. We agreed with all other investigators that the deeper the filter the coarser the filter medium could be. In applying our results it was decided that particle size and filter depths should be specified to suit the conditions of treatment, filter design and filter operation of each plant in question.

In most of our installations the Anthrafilt has an effective size of 0.70–0.73 mm. and a uniformity coefficient of less than 1.60 with a filter depth of 30 in. When a depth of 18 to 20 in. is all that can be placed in a filter the size is decreased to 0.58–0.62 mm. effective size. Where depths greater than 30 in. are available the size is increased accordingly. These general measurements are often modified to meet special conditions.

Filter Wash—Length and Strength

Fixing a length of time for filter washing is like fixing a length of time for washing hands. Three minutes may be plenty for hands that rock the cradle but entirely inadequate for hands that grease motors. Filters should be washed long enough to clean them—which means a short wash if they are not very dirty and a long wash if they are filthy.

The wash water velocity required to clean a filter should be high enough to give nearly 50 per cent expansion if water wash from below is used exclusively. If adequate agitation during washing is available, a low-velocity wash is effective and of course a relatively low expansion of filter bed.

Anthrafilt filters are usually washed with a 24-in. rise during the winter and a 30-in. rise during the summer. Where filter agitation is available, wash water velocities of 18 in. rise per minute, even for the coarsest material, have been found adequate. There will be no greater loss of Anthrafilt than of sand during the life of a filter. While Anthrafilt is half as heavy as sand, the weight of the individual particle is not half that of ordinary sand because a coarser particle of Anthrafilt is used.

One cause of dirty filters is the feeling that it is a disgrace to lose filter medium. A plant may use several carloads of alum per year without disturbance and yet if a little sand is washed from the filters it is the basis for criticism. The filter operator is usually instructed to use great care in washing the filter so as to lose no sand and, as a result, commonly underwashes. If he were instructed to be certain to wash filters so as to lose 5 per cent of the sand per year, the filters would be kept in a much cleaner condition. Two filtration plants in a large industrial city may be cited as examples: At one plant no sand has been purchased for 23 yr. and the filters are full of mud and cracks. At the other plant, one carload of sand is purchased each year and the filters are very clean. Where filters are provided with means for effective agitation of the material during backwashing, no sand loss is likely to occur.

Summary

Since Anthrafilt is essentially a carbon, and hence more nearly chemically inert than any other filter medium, it is well suited for many filtration processes. Its conchoidal fracture produces a particle which has the most desirable shape for use in filters; its low specific gravity and angular shape makes possible longer filter runs and more effective filter washing at lower backwash rates. Filter capacities have been increased from 25 to 100 per cent through the use of Anthrafilt.

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The Deterioration of Rubber Products by Micro-Organisms

By Claude E. ZoBell and Josephine D. Beckwith

ALTHOUGH rubber is generally regarded as being relatively inert, it is slowly attacked by certain micro-organisms. This first came to the attention of the senior author when, due to a shortage of glass-stoppered bottles, an attempt was made to supplement them with rubber-stoppered bottles for studying the B.O.D. of sea water. Almost invariably it was found that more oxygen was consumed by micro-organisms in sea water in the presence of rubber than in its absence. Even the small amount of rubber gasket exposed to the water in citrate of magnesia bottles caused an increase in the amount of oxygen consumed after 5 to 10 days incubation at 25°C. The examination of heat-sterilized and chemically preserved controls indicated that the majority of the increased oxygen consumption was caused by biological activity.

An extension of these observations and a precursory review of the literature reveals that various kinds of natural and synthetic rubber are attacked by numerous microbial species representing several genera.

A paper presented on October 29, 1943, at the California Section Meeting, Los Angeles, Calif., by Claude E. ZoBell, and Miss Josephine D. Beckwith, Scripps Inst. of Oceanography, Univ. of Calif., La Jolla, Calif.

Kinds of Micro-organisms Which Attack Rubber

Arens (2) attributed the red spots which appear on freshly prepared, unpreserved sheet rubber to the growth of *Bacterium prodigiosum*. Once established in the drying shed, this organism was found to cause considerable damage to sheet rubber. From red, blue and black spots on crude rubber, de Wilderman (12) isolated *Micrococcus prodiogiosus* and other chromogenic bacteria. The "spot disease" of crude sheet rubber exposed to moisture caused by the development of chromogenic organisms has been described by Eaton (14).

Blommendaal (5) demonstrated micrococcoid slime bacteria on crepe rubber showing white spots which appeared when the rubber was stored in the presence of air and moisture. Unlike mildews which commonly grow on the surface of crepe rubber, probably primarily at the expense of the nitrogenous impurities in the crude rubber, the "spot disease" bacteria are claimed to affect the usability of the rubber. Stevens (25) proposed the addition of 1.0 per cent p-nitrophenol to latex to prevent the growth of molds and other spot-forming organisms on crepe rubber.

Söhngen and Fol (21) observed the growth of certain soil micro-organisms on purified rubber treated with a min-

eral solution. *Actinomyces fuscus, Act. alba, Act. chromogens, Act. elastica* and another unnamed species of *Actinomyces* grew well in the mineral medium which contained only purified rubber as a source of energy. Fair growth was exhibited by *Mycobacterium rubrum, Mycobact. lacticola, Bacillus mesentericus* and *Pseudomonas fluorescens.* These organisms were isolated from garden soil and canal water by Söhngen and Fol.

According to de Vries (10, 11), the slow development of *Penicillium* and *Aspergillus* species on moist sheets of plantation crepe, which contain an average of 93 per cent of rubber hydrocarbons, causes a gradual loss in weight and physical properties of the rubber. The loss in weight was found to be as much as 22 per cent in 2 yr. and 30 per cent in 5 yr. The viscosity and elasticity of crepe rubber were markedly decreased.

From fermenting *Hevea* latex Corbet (1930) isolated *Gaffkya verneti, Micrococcus eatoni, M. ridleyi, M. epimetheus, M. chersonesia, Alcaligenes denieri, Bacillus pandora* and *Torulae heveae.* They discolored the latex and caused a slightly acid reaction which was shown not to be due to the fermentation of the methyl-1-inositol in the latex. Since there is no other substance present in latex except rubber hydrocarbon in sufficient quantities to account for the observed changes, Corbet concluded that the rubber hydrocarbon is attacked by the micro-organisms.

In earlier studies Corbet (7) found that heat-sterilized *Hevea* latex does not coagulate, which he attributed partly to the occurrence of thermolabile enzymes in the latex and partly to the action of bacteria. The inoculation of heat-sterilized latex with appropriate bacterial cultures resulted in coagulation after a short period of incubation. The bacterial count was described as tremendous in all cases when coagulation began. Predominating was *Bacillus pandora,* which attacked the coagulated rubber.

Novorgrudski (30) described a small non-motile coccus which forms yellow spots on rubber. These organisms, which are widespread in soil, decompose rubber and reduce the viscosity of the remaining rubber.

The decomposition of guayule latex by soil micro-organisms and by pure cultures of *Actinomyces* has been reported by Spence and McCallum (23) who found that 15 per cent of the rubber hydrocarbon disappeared and the remaining rubber had deteriorated in six weeks at 37°C. This observation was used to explain in part why there have been many failures to find appreciable quantities of rubber in guayule under certain conditions.

Besides finding four species of *Actinomyces* which decompose *Hevea* latex, Spence (22) found several strains of anaerobic bacteria which decompose the rubber in guayule latex.

Working with *Hevea* latex, Spence and van Niel (24) found that "the decomposition of rubber hydrocarbon by certain bacteria is both rapid and profound." After a few weeks at 30°C. the greater part of the rubber originally present in the latex had vanished, leaving a coagulum composed of a mass of bacteria in a residue bearing no resemblance to rubber. They found that after six weeks incubation at 20°C. soil organisms completely decomposed more than 20 per cent of the rubber in highly purified latex, "and that which remained was thoroughly deteriorated, soft and 'dead.'" Four species of *Actinomyces* were pri-

marily responsible for the deterioration of the rubber. These workers suggest that the products resulting from the microbial decomposition of natural rubber may provide a key to the study of how plants synthesize rubber.

Kalinenko (19) noted the destruction of rubber by *Actinomyces longisporus ruber, Act. aurantiacus, Aspergillus oryzae* and *Penicillium* species, which destroyed from 20 to 40 per cent of the rubber dispersed in mineral solution. *Azotobacter chroococcum, Bacillus mycoides, B. fluorescens, Sarcina ureae* and *Proteus vulgaris* were unable to assimilate the rubber hydrocarbon.

Bigger and Nelson (4) substantiated Harold's observation that the presence of rubber rendered distilled water growth-promoting for certain coliform bacteria. Questioning the ability of bacteria to assimilate rubber, these workers attributed the growth-promoting properties of rubber tubing and rubber stoppers to the talc dressing which they believed adsorbed nutrients from the atmosphere.

Using oxygen consumption, carbon dioxide production, the multiplication of micro-organisms and the deterioration of rubber as criteria, ZoBell and Grant (27) noted the oxidation of various kinds of natural and synthetic rubber by species of *Actinomyces, Micromonospora, Proactinomyces, Mycobacterium* and *Pseudomonas* which are quite widely distributed in the sea and in garden soil. Although they presented no data to prove that microbial activity plays an important role in the deterioration of rubber products, ZoBell and Grant concluded from their observations that the life of rubber products which remain in contact with moisture may be prolonged by retarding or preventing the activities of rubber-oxidizing micro-organisms.

Micro-organisms which oxidize rubber appear to be widely distributed in nature. Such organisms are almost invariably found associated with unpreserved latex and rubber products exposed to moisture. Old pieces of garden hose and the cracks in rubber products left in moist places have proved to be good sources of cultures.

Neither in nature nor in the laboratory do rubber-oxidizing bacteria appear to require rubber hydrocarbon for their growth. Though most abundant on moist rubber, rubber-oxidizing bacteria have been demonstrated in nearly all samples of marine mud, sea water, sewage, tap water and soil which have been examined for their presence. The enrichment culture technic has been employed to demonstrate the presence of rubber-oxidizing bacteria in such materials.

Following the method outlined by Kalinenko (19), garden soil has been found to contain from 5 to 500 rubber-oxidizing micro-organisms per gram (dry basis). Mineral-salts agar plates are coated with a thin film of rubber by allowing a benzene solution of purified rubber to evaporate on the surface of the agar. Included with the mineral salts is 0.01 per cent ammonium phosphate to provide for the nitrogen requirements of the organisms. The prepared plates are sprinkled with a small quantity of finely pulverized soil. After a week or two incubation at 25°C., the increasing transparency of the agar plates followed by the gradual perforation of the rubber film indicates the presence of rubber-oxidizing colonies. Various species of *Actinomyces* and *Proactinomyces* predominate on such plates with smaller numbers of *Micromonospora, Mycobacterium, Pseudomonas, Bacillus* and probably other genera.

Judging from the results obtained with two dozen species of soil and water bacteria selected at random from our stock cultures, several bacteria have the ability to attack rubber hydrocarbon. Mineral solution, including ammonium phosphate containing purified rubber as the only source of energy and organic matter, was inoculated in 150-ml. glass-stoppered bottles. Table 1 shows the amount of oxygen consumed by these cultures in 10 days at 26°C. in the presence of rubber after making corrections for their endogenous respiration in the same mineral solution without rubber. The bacteria were unable to multiply in the control mineral solution to which no rubber was added. All cultures were incubated in the dark.

TABLE 1

Oxygen Consumed by Bacteria Growing in Mineral Solution From the Oxidation of Purified Rubber

Culture	O_2 consumed—ppm.	Culture—Cont.	O_2 consumed—ppm.
None (sterile control)	0.30	Escherichia coli (SIO)	3.64
Pseudomonas neritica	5.23	Escherichia coli (R)	0.40
Pseudomonas aliphaticum	7.85	Serratia marcescens	1.99
Pseudomonas fluorescens	7.04	Serratia marinorubra	0.33
Pseudomonas sp. H-34	7.76	Alkaligenes fecalis	0.78
Bacillus subtilis	2.81	Sarcina lutea	0.20
Bacillus megatherium	0.17	Sarcina pelagia	0.37
Vibrio marinofulvus	5.35	Proteus vulgaris	0.40
Achromobacter stationis	0.29	Staphylococcus citreus	0.20
Flavobacterium marinovirosum	0.53	Micrococcus sedentarius	0.26

Since the rubber in the presence of 150 ml. of the mineral solution abiogenically consumed an average of 0.30 ppm. of oxygen under the experimental conditions, and since there may be an inherent experimental error of as much as 0.20 ppm. in determining the oxygen uptake, only the consistent consumption of more than 0.50 ppm. of oxygen is regarded as evidence of biological activity. Certain strains of *Escherichia coli* developed slowly, utilizing rubber as the only source of energy, but other strains failed to develop in such a medium.

Natural Rubber

Perfectly pure rubber, also called caoutchouc, is an unsaturated hydrocarbon having the composition $(C_5H_8)_n$. Caoutchouc is produced by a wide variety of plants, the best yields being obtained from the families Euphorbiaceae, Moraceae and Apocyanceae. Commercially, rubber is obtained chiefly from the plantation rubber tree, *Hevea brasiliensis*. Lesser quantities are obtained from *Hevea benthamiana, Castilla ulei, Castilla elastica, Manihot glaziovii, Fiscus elastica, Funtumia elastica* and other wild rubber trees. High percentages of caoutchouc also occur in the guayule plant, *Parthenium argentatum,* certain milkweeds, *Asclepias* species, the Russian dandelion, *Taraxicum kok-saghyz* and the Haitian shrub, *Cryptostegia grandiflora.* Caoutchouc occurs in many other plants.

The fact that rubber or caoutchouc is produced by numerous plants, and yet never accumulates in nature, indicates that it must undergo decomposition. Actually, pure rubber is relatively unstable, being oxidizable in the presence of atmospheric oxygen, particularly when exposed to light. The oxidation of rubber appears to occur most rapidly in environments where conditions are conducive to the growth of micro-organisms. The microbial deterioration of *Hevea* latex, which contains from 30 to 40 per cent rubber, is prevented by the addition of ammonia, caustic soda or other preservatives. Without such preservatives the latex ferments, resulting in the gradual destruction of the rubber hydrocarbon (8, 24). The microbial destruction of guayule latex and crepe rubber has been reported by Spence and McCallum (23) and de Vries (11) respectively.

When *Hevea* latex is cured by drying or acid coagulation, the resulting product contains from 90 to 95 per cent rubber. Air- and smoke-dried latex contains a much higher percentage of impurities than plantation crepe or sheet rubber which is acid coagulated. The average content of impurities of rubber prepared by the two methods is given below as compiled from various reference books:

Constituent	Air- or smoke-dried latex— Percentage	Acid-coagulated crepe rubber— Percentage
Nitrogenous materials	4 to 6	1 to 3
Acetone-soluble constituents	3 to 5	2 to 3
Mineral matter or ash	1 to 2	0.2 to 0.4
Methyl-l-inositol	1 to 2	traces
Sugars	0.3 to 0.5	traces

The acetone-soluble constituents consist primarily of stearic acid, oleic acid and various sterol-like compounds. From these data it is evident that the mere growth of micro-organisms on the surface of dried latex or crepe rubber is not conclusive proof that the rubber itself is being attacked because there are ample impurities to provide for bacterial multiplication. However, experiments with highly purified rubber, as well as with manufactured rubber articles, show that both pure rubber and compounded rubber articles are attacked by micro-organisms.

Compounding Ingredients

Manufactured rubber articles are prepared by compounding natural or synthetic rubber used singly or blended together in different proportions with hundreds of material to give certain desirable properties of elasticity, resiliency, extensibility, vulcanizability, tensile strength, conductivity, color wearing qualities, heat resistance, inertness towards solvents, etc. The commonest of the compounding ingredients may be classified in the following categories:

(a) Vulcanizing agents, of which sulfur is most important. Soft rubber generally contains from 1 to 10 per cent sulfur and hard rubber may contain from 10 to 50 per cent sulfur. Sulfur monochloride, selenium and other substances are sometimes used as vulcanizing agents.

(b) Accelerators of vulcanization, consisting of such substances as diphenylguanidine, *p*-aminodimethylanaline, thiocarbanilid, mercaptobenzothiazole (known to the rubber industry as Captax) tetramethylthiuram disulfide (known as Tuads), di-ortho-tolylguanidine dicatechol borate (Permalux) and other organic amines used singly or in combination. Compounded rubber generally contains from 1 to 5 per cent

accelerator. According to Dimond and Horsfall (13), Tuads and Captax are bacteriostatic, but whether they prevent bacterial activity when compounded with rubber is still unknown.

(c) Resistors, inhibitors or antioxidants, which consist of 0.5 to 4 per cent of para-amino-phenol (Rodinal), phenyl-alpha-naphthylamine (Neozone), diphenylamino ethane, certain aldehyde-amines or other compounds. While these substances retard the autoxidation of rubber and while some of the antioxidants are germicides, they may not inhibit the growth of micro-organisms in the form and concentration in which they occur in compounded rubber.

(d) As softeners, various hydrocarbon oils, waxes, tars, resins, fatty acids (usually stearic) and other substances are employed in concentrations ranging from 0.2 to 5 per cent. Larger quantities of fatice, or rubber substitutes made by treating vegetable oils with sulfur or sulfur chloride, are sometimes used as softeners or fillers.

(e) Reinforcing pigments or fillers consist of 1 to 60 per cent of one or more of the following: zinc oxide, carbon black, magnesium carbonate, lithopone, ferric oxide, zinc chromate, titanium oxide, lead oxide, certain clays, calcium carbonate, ground slate, metals, balata, gutta percha, fabrics, wood, etc. Wild rubber and low-grade plantation rubber sometimes contains sand, bark, leaf fragments and other impurities.

(f) Antimicrobial agents or antiseptics are only occasionally considered. Chlorothymol, p-nitrophenol, chlorinated dihydroxydiphenylmethane, sodium pentachlorophenate, mercurials and cyanides are among the long list of substances which have been used experimentally for this purpose. Manufacturers are giving more and more attention to the development of antimicrobial rubber for products continuously exposed to water.

Additional information on the composition of compounded rubber is given by Davis and Blake (9), Memmler (20), Fisher (16), Barron (3) and Flint (17).

In our initial experiments highly purified, 99 + per cent, non-vulcanized rubber obtained from the Goodyear Tire and Rubber Co., was dissolved in cp. benzene. After permitting the fractions insoluble in benzene to settle out, enough of the supernatant solution to contain 0.3 mg. of rubber was transferred to 150-ml. glass-stoppered bottles which were manipulated to form a thin film of rubber on the inside of the bottles as the benzene evaporated. After expelling the last trace of benzene, the rubber-coated bottles were filled with sterile water. Some of the bottles were inoculated with bacterial cultures and some were left uninoculated as sterile controls. Duplicate bottles were examined at the beginning of the experiment for bacteria and oxygen content, and other bottles were examined after different periods of incubation in a water bath at 22°C. The cultures were incubated in the dark. The protocol of a representative experiment is given in Table 2.

The oxygen content of the water was determined by a modified Winkler technic. Since iodine reacts with rubber, the water from each 150-ml. bottle was carefully siphoned into two 60-ml. bottles prior to introducing the Winkler reagents, from which iodine is liberated in the presence of oxygen.

A progressive increase in the amount of oxygen consumed was noted in the inoculated water in the presence of rubber, which was appreciably more than the amount of oxygen consumed by cultures without rubber or by rubber

TABLE 2

Oxygen Content of Sterile and Inoculated Mineral Solution, Some of Which Was in the Presence of the Equivalent of 2 mg. of Highly Purified Rubber per Liter, After Different Periods of Incubation at 22° C.

Experimental conditions	Oxygen content of water after—ppm.				O_2 consumed in 10 days—ppm.
	0 days	2 days	5 days	10 days	
No rubber, sterile control	6.86	6.88	6.85	6.87	0
No rubber, inoculated	6.80	6.72	6.64	6.51	0.29
With rubber, sterile control	6.83	6.52	6.30	6.29	0.54
With rubber, inoculated	6.79	5.47	2.31	0.82	5.97

in uninoculated water. After 10 days the equivalent of 5.14 ppm. of oxygen was consumed due to the action of bacteria on 2.0 ppm. of rubber (0.3 mg. of rubber per 150 ml. of water equals 2.0 ppm.). The quantitative oxidation of 2 mg. of rubber to carbon dioxide and water would require 6.58 mg. of oxygen, assuming rubber to be $(C_5H_8)_n$. Since 5.14 mg. of oxygen was consumed in the presence of 2.0 mg. of rubber, it is calculated that 78 per cent of the rubber was oxidized to carbon dioxide and water. Determination of the carbon dioxide content of the water substantiated this conclusion.

Oxygen consumption was accompanied by the multiplication of bacteria as shown by plate counts and the direct microscopic observation of samples. From the mass of bacteria produced it is estimated that 10 to 20 per cent of the rubber was converted into bacterial protoplasm. When added to the amount oxidized, it is found that the purified rubber is almost quantitatively utilized by bacteria, thereby confirming the observation of Spence and van Niel (24) that rubber hydrocarbon is completely decomposed by certain micro-organisms.

The perforation followed by the gradual and complete disappearance of thin films of rubber on inoculated agar plates and on glass slides immersed in culture solutions gives further evidence that rubber is attacked by micro-organisms.

Extensive Experiments

Experiments similar to the one summarized in Table 2 have been extended to include various micro-organisms both mixed and pure cultures from different sources employing several different kinds of manufactured rubber articles. The rubber articles were manufactured from natural rubber, reclaimed rubber and synthetic rubber.

Pure rubber is oxidized more rapidly by bacteria than most compounded rubber products. This is illustrated by the data in Table 3 which were obtained by exposing different rubber products to bacterial cultures in 150-ml. glass-stoppered bottles. The rubber products were cut into small pieces of approximately equal size to provide for the exposure of equal areas of rubber surface, because it has been found that the rate of oxidation is directly proportional to surface area rather than the weight of rubber. The amount of rubber in rubber products varies within wide limits depending upon their content of compounding agents.

Pure rubber or caoutchouc may be

oxidized more readily than compounded rubber either because in the latter the hydrocarbon molecules are bound with the compounding agents in such a way that they are less susceptible to attack, or some of the compounding agents may be bacteriostatic. The problem of anti-microbial properties of compounding agents cannot be considered in this paper which is concerned primarily with establishing that under conditions conducive to the growth of micro-organisms, rubber products are subject to microbial attack.

The action of bacteria on the inner lining of garden hoses is believed to be one of the chief causes of their failure. The lining usually consists of natural or reclaimed rubber compounded with various fillers. Judging from the rate at which small pieces of the lining of intermediate grade (pre-war, guaranteed for 5 yr.) garden hose are decomposed by bacteria in water in controlled experiments, it is estimated that as much as 1.0 g. of rubber may be oxidized per day in a 50-ft. length of hose left full of water at 22°C. In a year this would amount to more than ½ lb. of rubber under optimal conditions for the activity of micro-organisms.

Besides the loss of rubber, bacterial attack causes rubber to swell and it probably weakens the structure of the rubber product. Fortunately, conditions are rarely optimal for bacterial activity in garden hoses. Oftentimes they are drained, or the hose may be left only partly filled with water. During the time that water under pressure is flowing through the hose, bacterial activity will be minimized. When manufactured from an abundant supply of cheap rubber, the bacterial deterioration of garden hoses may be of no economic importance but when the stock-piles of rubber are rapidly diminishing, the problem of the bacterial deterioration of rubber may merit consideration.

Motivated by his interest in the early failure of rubber products used in water distribution systems which are

TABLE 3

B.O.D. of Approximately 15 sq.cm. of Various Kinds of Rubber Products After 5 Days Incubation in 150 ml. of Mineral Solution at 22° c.

Rubber Product	Oxygen consumed in 5 days—*ppm.*		B.O.D. of Rubber Product—*ppm.*
	Sterile Control	With Bacteria	
None (mineral solution only)	0	0.31	—
Black rubber stoppers, "pure gum"	0.84	4.27	3.12
Amber rubber tubing, "pure gum"	0.72	5.14	4.11
Red rubber tubing, no fabric	0.53	5.80	4.96
White rubber tubing, no fabric	1.07	3.56	2.17
Rubber tissue, dental dam	0.41	5.09	4.27
Rubber gaskets, for mason jars	0.19	4.28	3.78
Rubber gaskets, for CM.* bottles	0.36	4.12	3.45
Rubber lining from garden hose	0.42	5.98	5.25
Purified caoutchouc, 99+ per cent rubber	0.45	6.82	6.06

* CM is used to abbreviate citrate of magnesium bottles.

costly to service, Carl Wilson, consulting technologist in water supply, provided us with some rubber rings or gaskets used in connecting asbestos cement pipe, rubber gaskets used in water meters and a hard rubber plate or disc used in water meters. The effect of bacteria upon these products is summarized by the data in Table 4.

The mere utilization of oxygen in the presence of rubber products does not necessarily prove that rubber itself is oxidized but when corrections

TABLE 4

Oxygen Consumed in 10 Days by Comparable Surface Areas of Different Rubber Products in Sterile Mineral Solution and in a Similar Solution Inoculated With Bacterial Cultures

Rubber Product	Oxygen Consumed in 10 Days—*ppm.*		
	Sterile water	Culture No. 43	Culture No. 87
None (mineral solution only)	0	0.40	0.34
Gaskets for asbestos cement pipe	0.45	3.99	4.73
Water meter gasket	0.55	5.16	6.77
Hard rubber water meter plate	0.48	1.07	1.32
Neoprene rubber stopper	0.63	5.17	3.46

are made for the controls, the B.O.D. is indicative of the quantity of rubber product that has been oxidized. For practical purposes it is inconsequential whether the rubber hydrocarbons or the compounding agents used in the manufacture of the rubber product are oxidized. Either would contribute to the deterioration of the product. Observations on the B.O.D. supplemented by data on the loss of weight of rubber products over a long period of time show that microbial activity accelerates the deterioration of rubber products five- to fifty-fold.

There is some evidence that the disagreeable taste imparted to water stored in rubber receptacles is intensified by microbial activity. Sterile water stored in contact with rubber tastes less bad than otherwise comparable water previously inoculated with rubber oxidizing micro-organisms.

An anonymous (1) editorial in a trade journal relates that the destruction of rubber insulation by fungi causes the failure of electric conduits. Various preservatives have been used to prevent the microbial deterioration of rubber insulating materials subjected to moisture.

Synthetic Rubber

The list of synthetic rubbers including Neoprene, Butaprene, Buna S, Buna N, Butyl, Thiokol, Perbunan, Hycar, Duprene, Chemigum, Agripol, Norepol, Flexon, Ameripol and Koroseal is being extended as new formulas are developed. Although the synthetic rubbers differ from each other in many respects, they all have certain properties in common with natural rubber. Most of them are polymers or co-polymers of unsaturated hydrocarbons such as butadiene ($CH_2=CH-CH=CH_2$), methylbutadiene or isoprene, chlorobutadiene or chloroprene, isobutylene ($(CH_3)_2C=CH_2$), acrylonitrile ($CH_2=CHCN$), styrene ($C_6H_5-CH=CH_2$), or allied compounds. Neoprenes are polymers of chloroprene. Buna-S types are co-polymers of butadiene and styrene. Buna-N types are co-polymers of butadiene and acrylonitrile. Butyl rubber is a co-polymer of isobutylene, butadiene and isoprene. Thiokol RD is a buna-N type of synthetic rubber. Thiokols A, B and FA made from ethylene chlo-

ride or dichloroethyl ether and sodium tetrasulfide differ markedly from the other synthetic rubbers. The other names mentioned above are trade names applied to synthetic rubber, most of them being buna-N types.

A priori one may expect the synthetic rubber to be attacked by bacteria because natural rubber is attacked and most kinds of hydrocarbons are oxidized by certain micro-organisms. According to Bushnell and Haas (6), Stone et al. (26), ZoBell et al. (28) and others, micro-organisms which attack hydrocarbons are widely distributed in water and soil. In general, unsaturated hydrocarbons are attacked more readily than saturated compounds, and long chains are attacked more readily than short chains. The oxidizability also seems to be a function of the number of side-chains, iso-compounds generally being more susceptible to bacterial oxidation than normal hydrocarbons. Most synthetic rubbers are long-chain unsaturated hydrocarbons with many side chains attached.

Most uncured synthetic rubbers are very unstable, and even when compounded with resistors or antioxidants they appear to be susceptible to bacterial attack. Table 5 illustrates the effect of bacterial activity on a series of synthetic rubbers provided by the United States Rubber Co. A sample of highly purified, 99 + per cent, natural rubber and one Neoprene (rubber stopper) are included for comparison. The rubber was distributed in glass-stoppered bottles so that approximately equal areas of each were exposed to the water. Sea water diluted with distilled water was employed to provide the minerals essential for the growth of micro-organisms. Part of the bottles were inoculated with enrichment culture No. 43 isolated from sea water,

TABLE 5

Oxygen Consumed in 10 Days at 26°C. by Comparable Surface Areas of Different Kinds of Rubber in Sterile Mineral Solution and in a Similar Solution Inoculated With Bacterial Cultures

Description of rubber	Oxygen Consumed in 10 Days—ppm.		
	Sterile control	Culture No. 43	Culture No. 87
None (mineral solution only)	0	0.40	0.58
Buna S (butadiene and styrene type)	0.70	5.69	6.28
Thiokol (organic polysulfide type)	0.62	2.22	3.34
Hycar (Buna N type)	0.82	3.90	3.28
Butyl (Isobutylene co-polymer type)	0.77	1.95	2.06
Experimental elastomer 8-D	0.67	2.54	1.69
Experimental elastomer 8-E	0.65	1.94	2.90
Experimental elastomer 8-F	1.45	2.24	4.86
Neoprene (du Pont stopper)	0.97	5.17	3.46
Purified natural rubber	0.47	6.62	7.48

part were inoculated with culture No. 87 isolated from fresh water and part were left uninoculated as sterile controls. The oxygen content of the water was determined in duplicate at the beginning of the experiment and after 10 days incubation at 26°C. The amount of oxygen consumed by the rubber in the presence and in the absence of bacteria is summarized in Table 5.

Multiple Formulas

The data in Table 5 indicate that bacteria promote the oxidation of various kinds of synthetic rubber. However, such data are of no significance for appraising the relative resistance of a general type of rubber to oxidation without information on the formulas used in compounding the particular product, there being literally hundreds

of formulas for giving the rubber products certain desirable properties.

Further experiments employing oxygen consumption as well as changes in the weight and consistency of the rubber itself show that rubber products manufactured from Neoprene, Duprene, Butaprene, Chemigum and Ameripol are attacked by micro-organisms in mineral solutions. Although we do not have the formulas used in compounding the synthetic rubber products which were examined, we understand that they contained no natural or reclaimed rubber. In these experiments which were designed to show whether a given product is subject to microbial attack rather than to obtain data on the relative rates of biological decomposition of different rubber products, most kinds of synthetic rubber products, including laboratory appliances such as stoppers and tubing, appeared to be equally, or possibly more, susceptible to oxidation by bacteria than products manufactured from natural rubbers. Polysulfide thiokols (types A and B), vinylites and chlorinated rubbers appear to be relatively resistant to bacterial attack but these products have few of the characteristics of live rubber.

Discussion

The foregoing observations indicate that the anti-microbial properties of rubber products should be taken into consideration in the selection or development of rubber which is to be exposed continuously to moisture under conditions favorable for the growth of micro-organisms. This is not a simple problem. Substances which are normally bacteriostatic may be biologically inactive when combined with rubber hydrocarbons or rubber compounding agents. For example, Dimond and Horsfall (13) found that while mercaptobenzothiazole is a potent anti-microbial agent by itself, it is rendered ineffective as an inhibitor of micro-organisms when mixed with zinc oxide which is commonly used in compounding rubber products. On the other hand certain bacteriostatic agents may impart undesirable properties to the rubber.

Besides the technological difficulties which are involved, the problem of preventing the bacterial decomposition of rubber hydrocarbons is complicated by the fact that a good many cyclic or aromatic compounds of the benzene series which are commonly used as germicides or preservatives are attacked by some of the hydrocarbon-oxidizing bacteria. Gray and Thornton (18) found bacteria to be quite widely distributed in the soil, which oxidize phenol, cresol, phloroglucinol, toluol and recorcinol. Erikson (15) studied *Micromonospora* species from mud, which utilize toluol, phenol, resorcinol, cresol, β-naphthol, naphthalene and paradichlorobenzene. ZoBell et al. (28) have observed the growth or water bacteria in the presence of 1.0 per cent phenol and a like concentration of emulsified tri-cresol.

The problem of the role of micro-organisms in the deterioration of rubber products and its prevention has received relatively little attention although considerable work has been done on the microbiology of *Hevea* latex and crude crepe rubber. This is because latex and crepe rubber are subjected to conditions which favor microbial activity, while proportionally only small quantities of manufactured rubber products are exposed to environments where appreciable microbial activity is possible. The extensive growth of micro-organisms on rubber

has been observed only in the presence of moisture at a favorable pH, temperature and oxygen tension. For most rubber products the effect of microbial oxidation is either non-existent or insignificant compared with the deterioration caused by heat, light, oil, abrasion, air, acid, alkali, etc.

Even in the presence of biologically balanced mineral solution containing available nitrogen, rubber is only slowly attacked by micro-organisms. In the experiments summarized on the preceding pages, from 0.2 to 0.5 mg. of rubber was oxidized in 10 days at 25°C. by active cultures growing on around 250 to 300 mg. of rubber cut into small pieces so that about 15 sq.cm. of surface area was exposed. At this rate the micro-organisms would decompose from 3 to 10 per cent of the rubber initially present in a year, or 5 to 50 times as much as undergoes spontaneous or abiogenic deterioration in a mineral solution during a like period. de Vries (10) noted a 22 per cent loss in weight in crude crepe rubber stored in the presence of moisture for 2 yr. and a 30 per cent loss in 5 yr. which he attributed to the activities of micro-organisms.

It is difficult to generalize concerning the percentage decomposition of rubber because the rate of bacterial oxidation is directly proportional to the surface area exposed to active cultures and bears little relationship to the total quantity of rubber present. Moreover, the rate of oxidation increases progressively from day to day after the organisms have started to grow on the surface of the rubber until a slimy film is established. Later in a closed system when D.O. is depleted from the surrounding water, bacterial oxidation ceases.

The oxygen tension of the water does not influence the rate of bacterial oxidation until the oxygen is nearly depleted. However, the bacterial as well as the abiogenic oxidation of rubber is influenced by the oxidation-reduction potential of the medium. After the oxygen content is reduced to less than 0.3 ppm., oxygen may be consumed by respiring bacteria on the surface of oxidizable substrates more rapidly than it can be replaced by diffusion, under which conditions the oxygen tension becomes a limiting factor. Using a variety of substrates, ZoBell and Stadler (29) demonstrated that the respiration of water bacteria is independent of oxygen tension within the examined ranges of 0.30 to 36.46 ppm.

Summary

Rubber hydrocarbon is attacked by a large number of micro-organisms including species of *Actinomyces, Proactinomyces, Micromonospora, Mycobacterium, Aspergillus, Penicillium, Pseudomonas, Bacillus* and other genera. Rubber is decomposed more rapidly by mixed cultures than by pure cultures.

Oxygen consumption, carbon dioxide production, the multiplication of micro-organisms and loss in weight of the rubber show that the rubber is being attacked in a medium which has no other source of carbon or energy. Microbial activity also causes rubber to swell.

Pure natural rubber or caoutchouc is more susceptible to oxidation by micro-organisms than compounded rubber products although many rubber products are attacked.

Microbial activity may play an important role in the deterioration of rubber products which are exposed to moisture under conditions favorable

for the growth of micro-organisms. Certain rubber products used in water distribution systems are subject to microbial attack. From experimental data it is estimated that up to one-half pound of rubber from the inner lining of a 50-ft. length of garden hose may be oxidized in a year if water is left standing in the hose.

Some synthetic rubbers are just as susceptible to microbial oxidation as natural rubber while others appear to be relatively resistant to microbial attack.

It is recommended that the antimicrobial properties of rubber be taken into consideration in the selection or development of rubber products which are to be continuously exposed to moisture.

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Discussion

Harry E. Jordan*

The authors of this paper have recorded a series of studies of considerable interest. Much of the material presented relates to the extent of bacterial growth on *crude* rubber. As a record of the susceptibility of this vegetable derivative to bacterial action, the information is valuable for anyone who has need for fundamental knowledge of the nature of rubber.

When the authors refer to studies upon compounded commercial rubber products, one gains the impression that the data presented might produce substantially erroneous impressions. With this statement of the authors there can be no disagreement—"the anti-microbial properties of rubber products should be taken into consideration in the selection or development of rubber which is to be exposed continuously to moisture under conditions favorable for the growth of microorganisms." One can parallel that statement with the suggestion that evidence is lacking that microbial deterioration of compounded rubber as used in water works practice is a problem of engineering or economic importance. In other words, rubber as used in meter discs and gaskets, as rings for mechanical couplings of water pipe, as valve discs or steam driven pumps, etc., has not shown a record of deterioration or failure sufficient to cause engineers to search for substitutes.

The deformation of meter discs by hot water backflow is a serious problem and thermally resistant substitutes for rubber have been sought. But the wasting away of meter discs in service has not been a problem as would be the case if microbial destruction were continuous or general.

Rubber rings under compression in mechanical joints on water lines have known service records of more than forty years with disintegration (which might be attributed to microbial action) unheard of in the water works field.

Water works engineers have learned much about the deterioration of ferrous metal as a result of bacterial action. But with the evidence of such destruction of ferrous metal, the engineers move toward its more adequate protection.

We must conclude that while the authors' studies indicate that microbial activity *could* promote the disintegration of rubber products as used in water works practice (meter discs, pump valves, pipe gaskets, etc.), other factors not demonstrated by the au-

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thors, evidently *limit or block off* bacterially induced deterioration.

There appears to be reason to apprehend that disintegration of cured or vulcanized rubber will neither cause the failure of a water line where rubber gaskets are used, nor the failure of a water meter to register where a rubber disc is the moving, measuring unit. In other words, what the authors have done is to open the door to further investigation by themselves, or by others, to show why, in practical experience, the deterioration which they postulate, does not occur.

Authors' Closure

Perhaps we failed to qualify sufficiently our experiments with rubber gaskets. Our thesis is that bacteria *do* attack pure rubber and rubber products. The evidence is convincing. However, one could easily get the wrong impression regarding the quantity of certain rubber products which may be oxidized by bacteria in the absence of more explicit information on certain experimental conditions.

In order to provide for considerable surface area, "the rubber products were cut into small pieces" (note descriptive sentence under Table 3). As a matter of fact, the rubber products were cut into such extremely small pieces that thousands of times as much surface area was exposed as is exposed by the whole rubber product. Unless considerable surface area of some of the compounded rubber products is exposed to the action of bacteria, no oxidation can be demonstrated by ordinary experimental procedures.

We believe that slow bacterial deterioration of such rubber products as we examined does occur although under practical conditions the rate of deterioration is very slow because relatively little surface is exposed. In view of the modern trend in the manufacture of synthetic rubber products, the possibilities outlined in our paper may merit attention.

Army Post Water Plant Operation in the Seventh Service Command

By Chester A. Obma

A BRIEF description of the Army Service Forces' organization may be helpful in understanding how Army construction, maintenance and utility operation is handled. The Chief of Engineers, as a Staff Officer of the Commanding General, Army Service Forces, is responsible for all military construction, the operation and maintenance of all utilities at Army posts and the maintenance of all real property. The Chief of Engineers formulates all basic policy, provides certain standard designs, procures centrally certain materials and equipment and exercises general supervision of all construction, operation and maintenance functions. The direct technical supervision of operation and maintenance of utilities, and maintenance and repair of real property in Continental United States is done by the nine Service Commands and is the responsibility of the Service Command Engineer Staff Officer of the Commanding General of the Service Command. Inasmuch as he is also the Division Engineer, the actual direction of this work is carried on by the Chief of the Repairs and Utilities Branch in this Service Command. The repairs and utilities functions of each post are the responsibility of the Commanding Officer and are carried out by a Staff Officer known as the Post Engineer. Down through each of these echelons of command, the repairs and utilities functions are performed by the Corps of Engineers. The technical supervision of water works exercised by this Service Command is handled by the Water and Sewerage Section containing five sanitary engineers and a water supply chemist. Monthly operating reports from the posts are reviewed here. Technical assistance, both routine and "trouble shooting," is furnished to the Post Engineers. They also make special studies on various operating problems, special case studies of various individual problems and devise or design corrective measures and improvements. Projects consisting of non-recurrent maintenance and additions to existing utilities costing over $1,000 are reviewed and passed upon by this group. Projects of this category in excess of $10,000 are reviewed and referred to the office of Chief of Engineers for final approval. The water conservation program described in the Kessler, Sundstrom and Tomek paper* is carried on by this group.

A paper presented on October 15, 1943, at the Missouri Valley Section Meeting, Des Moines, Iowa, by Chester A. Obma, Capt., C.E., Chief, Utilities Section, Repairs & Utilities Branch, 7th Service Command, Omaha, Neb.

* Jour. A.W.W.A., **35**: 1009 (1943).

New construction is handled by a different chain of command which is under direct control of the Chief of Engineers. In each Service Command, the new construction is handled by the Division Engineer responsible directly to the Chief of Engineers. He, in turn, allocates jobs to the various districts retaining general supervision, procurement of certain materials and liaison with the various using services. The district has a resident engineer officer on each job or group of jobs known as the Area Engineer. Owing to the huge amount of construction required, the districts are unable to do all of their own engineering and engage civilian architects and consulting engineers on architect engineer contracts to do the designing and to supervise the construction of many of the jobs under the Area Engineer. In this manner most of the water plants and water systems, as well as other utilities at Army posts in this Service Command, have actually been designed and their construction supervised by civilian consulting engineers. For this reason the credit for the fine work in this tremendous program can be taken by the engineering profession in general, rather than any particular group. Conversely, its shortcomings, by the same token, can be charged to this profession.

Operation of Army-Owned Plants

Most Army-owned manufacturing plants such as ordnance plants have been constructed by the Corps of Engineers, but are operated under contract by various private corporations under the general supervision of one of the technical services such as the Ordnance Department or the Chemical Warfare Service. In such plants the operation and maintenance of utilities and the maintenance and repair of real property, as well as manufacturing equipment, is done by the operating company and the Service Commands have no repairs and utilities functions.

While the Corps of Engineers is responsible for the operation of water supplies, the Medical Department is responsible for their sanitary supervision under the Army regulation which makes the Post Surgeon responsible for all environmental factors affecting the health of the post. The Post Surgeon is required to make a bacteriological analysis of the water supply at least once a month. In most stations this is done a good deal oftener. He also makes frequent inspections of the source of supply and makes regular checks of the chlorine content. The Post Surgeon has his own laboratory facilities at many of the posts. Where such facilities are not available, water samples are sent to the Service Command Medical Laboratory at Ft. Omaha. The criterion for potability is the absence of bacteria of the coliform group. The test as set forth in *Standard Methods* is used. Total bacterial counts are not normally made as only minor sanitary significance is attached to this test. At the larger posts, a Sanitary Corps Officer, usually a Sanitary Engineer, is attached to the Post Surgeon's Staff and handles the sanitary supervision of the water supply for the Post Surgeon. This policy of interlocking responsibility has worked out very well. Recommendations regarding the sanitary quality of a water supply made by a Sanitary Corps Officer or by a Post Surgeon are promptly acted upon by the Repairs and Utilities Branch. All new sources of water supply must be approved by the Medical Branch. At the Service Command headquarters, a very close liaison is maintained between the Medical

Branch and the Repairs and Utilities Branch through the Medical Branch Sanitary Engineer.

Types of Water Supplies—7th Service Command

In this Service Command there are 82 posts having individual water supplies. This, of course, does not count downtown leased facilities such as hotels, storage depots and quartermaster laundries. Of these, 42 have wells as their source of supply, 36 purchase their water from an adjacent municipality, 2 use springs, while only 2 posts obtain their water supply from surface sources. Each supply has two or more sources, except in unusual cases. In the case of well supplies, if two wells are not enough, additional wells are constructed to provide ample standby capacity. Where city water is provided for a post some distance from town, ground storage reservoirs and booster pumps are provided on the post to furnish at least a 24-hr. supply in the event of a break in the transmission main.

Chemical Content of Water

In the 42 well supplies, there is just about every type of well, varying from shallow dug wells to drilled wells 4,645 ft. deep. The majority of the well supplies, however, are screen type wells constructed in alluvial gravels. This type of well has been quite satisfactory from the standpoint of yield. Chemically, these waters are somewhat high in minerals, particularly bicarbonates, and occasionally are iron bearing. Bacteriologically, their record has been rather good but, because there is a potential contamination hazard in this type of well, the water is always chlorinated. A number of the wells utilize concrete well screens. These have worked out very well, particularly in the coarser gravel formations. A rather odd thing happened to one of the wells at a post along the Missouri River. It was inundated during the spring flood, and a month or so later its drawdown increased from 18 in. to approximately 19½ ft. At this lower level the pump was in danger of drawing air. Investigation, in co-operation with the 7th Service Command Medical Laboratory, disclosed that a growth of *Gallionella,* an iron bacteria, was present and was presumably clogging the screen. Approximately 150 lb. of chlorine was introduced into this well and allowed to stand for a week. The well was pumped to waste and the drawdown was reduced about 10 ft. Additional treatment is contemplated in the hope of restoring the well to its original drawdown level. If additional chlorination does not help, it may indicate deposition of iron oxide. Acid treatment, of course, cannot be used and an attempt may be made to remove this deposit with sodium bisulfide.

Cooling Facilities

The deep drilled wells are located at posts in the Black Hills area and on the eastern slope in Colorado. The wells in the Black Hills country are notable for their high mineral content and high water temperature. At two posts in this vicinity cooling facilities were necessary. At one there is a type of evaporative cooler similar to those used with large deisel engines; and at the other what amounts to a surface cooler in reverse, that is, the water to be cooled is inside the cooling coils while the cooling water is applied to the outside. These deep wells have been constructed using oil field methods. Drilling was done with

rotary rigs, casings were extended to the bottom of the well and perforated in place by gun perforators, after which the wells were acidized. In general, these wells are rather expensive to operate and maintain. In one case the dynamic level drops to approximately 750 ft. below the surface. In another case the water is very corrosive and a special type pump column is needed. In the Colorado wells, the water-bearing formation is rather loosely consolidated and sand is always more or less of a problem. Wells of this type are used only because no other source of water is available.

Filtered Supplies

Springs are utilized as sources of supply at two smaller posts also in the western portion of the Service Command. These sources of supply were likewise utilized only because no other supply was available. Both of the springs have been improved by constructing infiltration galleries of perforated corrugated iron pipe and concrete curbs extending well above the permanent grade. This has improved the yield considerably and provided some sanitary protection. In both cases, however, the springs are somewhat affected by protracted periods in dry weather, and are not entirely satisfactory sources of supply.

The two filtered surface water supplies are located at large cantonments in Missouri. The plants are quite similar and have no unusual design features. In both cases the raw water is taken from unusually clear Ozark streams and no additional treatment is needed other than alum coagulation, sand filtration and chlorination. Filter runs in these plants average from 45 to 60 hr.

Pumping Problems

Pumping problems in this area have not been particularly difficult. The nature of the construction program, however, has resulted in some well pumping difficulties that the average water works would not experience. When the construction program was at its height, it was necessary to order pumps before wells were drilled because it took three to six months to get delivery. In order, therefore, to have a water supply available when the post was to be activated, head conditions and yield of the well had to be estimated. In a number of cases some very accurate guesses were made. In others, however, the head conditions actually turned out to be lower than anticipated, and overloaded motors resulted. Accordingly, it was necessary to check the electrical input to the motors on the well pumps and where overloads were found, pull the pump and remove one or more of the pump impellers. This procedure is believed more satisfactory than simply throttling the pump.

At an Army post in Colorado, booster pumps were provided on a supply which took off from a large transmission main carrying the water supply of the nearby city. The pumps selected were based on the water pressure in this main during the winter months. Last summer, however, when people in town began sprinkling their lawns, the pressure in the transmission main dropped to a point where the head capacities of the pumps were not sufficient to fill the elevated tank. The pumps had to be replaced.

The quality of the pumping equipment furnished in this Service Command has been, in general, excellent. Where this equipment was used under

the conditions for which it was designed, uniformly satisfactory results have been obtained. Most of the pump manufacturers have given excellent service and have conscientiously followed up on their installations to see that the Army was getting efficient performance.

Hydraulic Problems

Certain hydraulic problems have developed both in transmission mains and in distribution systems. Considering the tremendous pressure under which the designers operated and the scarcity of the varied, special equipment, it is really surprising that there have not been more problems of this sort. There have been two cases of damage to long transmission mains caused by water hammer. In one case, the main conveyed water from an adjacent municipality to an air base seven miles from town. The air base was at a lower elevation than the city, resulting in a water pressure at the meter of around 120 lb. A direct-acting pressure regulator was installed to reduce the pressure to 60 lb. in the post distribution system. No elevated storage was provided in the distribution system nor was there any surge protection provided in the transmission main other than a very inadequate 2½-in. pressure relief valve at the regulator. Fluctuations in the demand on the post naturally caused the pressure regulator to open and close rapidly, which in turn set up water hammer waves in the transmission main that promptly blew off all the air reliefs. The contractor, thinking it his fault, went out and wired them all down. Shortly thereafter, a joint failed. About that time it was realized what was going on and the post was changed over to the emergency supply. It is planned to install a 6-in. pressure reducing valve operating at 10 psi. higher outlet pressure and a 1-in. line without a pressure reducer, in parallel with the 10-in. reducing valve. This should eliminate the water hammer because the flow in the transmission main is not permitted to fluctuate widely as it originally did.

The other case of water hammer in a long transmission main developed at a Kansas cantonment, where four individual wells pump into a transmission main terminating in a ground storage reservoir on a hilltop about five miles away. When this supply was constructed, it was impossible to get cone valves or other types of slow-closing valves, so each pump was equipped with a gate valve. It was found after the pumping plant had been put into service that the manually-operated gate valves could not be closed while the pumps were operating because of the high water velocities. As a result, some water hammer develops each time a pump is shut off and has caused a number of minor joint failures. We hope to get proper slow-closing valves on each pump, however, before there is a serious failure on this line.

Pressure Variation

At several smaller posts there are direct pressure systems which have caused a certain amount of hydraulic problems. On these systems the pressure varies rather widely. Fluctuating pressures have set off the fire alarms on some hospital sprinkler systems. These were finally eliminated by the installation of small booster pumps around the clapper valve and retarding chamber to maintain a pressure on the sprinkler side of the system which is higher than any of the peaks on the distribution system. Direct pressure systems also require 24-hr. attendance

at the water plant, in order to have someone there to start the gasoline-driven auxiliary engines in case of a fire. Unless the gas engines are running, a power failure while the fire pumpers were operating would almost immediately result in a vacuum on the distribution system. These and other reasons have led us to conclude that elevated storage tanks are essential for smooth and economical operation of any water system except, possibly, very large systems.

Water Treatment

Only three of the well water supplies in this area were of such a character as to require complete treatment. The first of these is in an established permanent post whose wells are in an alluvial gravel. The water has an average of about 15 ppm. iron, an average carbonate hardness of about 350 ppm. and non-carbonate hardness of about 100 ppm. The treatment consists of aeration followed by a conventional type of lime-soda softening and filtration. The plant is well designed and has given satisfactory results since the time it was constructed in 1934. The water treatment plant at another post having very similar wells also uses lime-soda softening following aeration. At this plant, however, a (Spaulding type) circular mixing and precipitation unit is used. It has not been in operation long enough for any definite conclusions to be drawn. The operation to date has been satisfactory but it has been found that the plant must be operated at a constant rate or it is difficult to maintain the lime slurry blanket. Another ½-mil. gal. storage tank is being added to this unit to permit operation at a constant rate during the summer high-consumption period.

The third water treatment plant is located in the Black Hills district and is used to treat a deep well water having a temperature of 139° and a very high content of sodium, chlorides and sulfates, a total hardness of 633 and a carbonate hardness of 397. Salt-regenerated carbonaceous-zeolite softeners are used. After softening, the water is cooled. This plant has been in operation just about a year and has produced satisfactory results, considering the type of raw water.

Water treatment plants for the entire supply, in spite of advertisements to the contrary, are used by the Army only on supplies like the one just described, where the water simply cannot be used without treatment. The initial cost, both in money and critical materials, must be more than offset by savings in both operation and maintenance computed on the basis of both money and materials cost. Unit softeners are provided for boiler plants and laundries where the savings are obvious. Unit softeners are provided at hospital surgeries where the use of hard water, for sterilizing surgical instruments, will damage them. Unit zeolite softeners are also installed in mess halls where the hardness of the water exceeds 400 ppm. This is necessary because the insoluble film of calcium stearate on dishes washed in this hard water makes it difficult to sterilize them properly. On softer supplies, a 30-sec. rinse with 180° water satisfactorily removes this calcium stearate film.

Threshold Conditioning

As previously mentioned, one of the guiding factors in the Army's water treatment program is the conservation of critical materials. It is obvious that, under certain conditions, lack of treatment would result in the waste of criti-

cal materials. While the Army has access to many materials that the municipalities do not, great care is taken to prevent abuse of these priorities. Critical materials are used primarily for combat equipment, munitions and facilities for their manufacture. For all other purposes, non-critical materials are used to the fullest extent and the amount of critical materials is held to the rock bottom minimum. With this policy in mind, the threshold conditioning of water supplies has proven to be very useful by permitting successful treatment of scale-forming and corrosive waters with the use of only a very small amount of critical material. By "threshold conditioning" is meant any chemical treatment of water with small concentrations, in amounts less than 25 ppm. of non-toxic chemicals either mineral, organic or both, which are introduced into the potable water supply for the prevention or control of scale formation, corrosion, or both. Kessler, Sundstrom and Tomek have described their studies in this field, the program that was developed in the office of Chief of Engineers, and the results in their excellent paper. In this Service Command, our experience with this program has brought out no new features, but there have been some rather interesting results.

Portable Laboratory

A chemist with a portable trailer laboratory makes on-the-spot analyses and determines the proper threshold conditioning. Several samples are tested on each post for determination of the action of the water as it passes through the distribution system. The following tests are made on each sample: temperature, color, odor at 90°C., turbidity, phenolphthalein alkalinity, methyl orange alkalinity, soap-consuming power, free carbon dioxide, hydrogen-ion concentration, dissolved oxygen, free chlorine and total iron. When additional tests are considered necessary for the recommendation of proper treatment, samples are sent to the 7th Service Command Medical Chemical Laboratory at Ft. Omaha for chemical analyses. At the same time as the tests are made, an inspection of the piping system is also made to determine the extent of scale formation and corrosion. Test nipples are placed on hot-water feed lines on hot-water heaters so that periodic inspections can be made to determine the progress of the treatment for conditioning the water.

Red Water Problems

Chemicals used are polyphosphates (such as Calgon or Nalco 918), silicate of soda, sodium tetraphosphoglucosate and sodium carbonate. Polyphosphates have been found to prevent the precipitation of dissolved iron by keeping it in solution in the presence of dissolved oxygen. Most of our "red water" problems have been found to be due to this precipitation of dissolved iron in the presence of oxygen rather than corrosive action of the water on the pipe. It is not known as yet what effect this treatment has on the growth of iron bacteria such as crenothrix, etc., although we do know that they can be controlled by chlorination. Another property of polyphosphates that our experience has confirmed is the prevention of the precipitation of calcium carbonate scale at temperatures as high as 160°F. Over 160°F., our results are, to date, inconclusive. No evidence has been obtained which would show that polyphosphates effect the efficiency of zeolite treatment.

Tetraphosphoglucosate has accom-

plished the same results as the polyphosphates at the installation where it is being tried.

Silicate of soda is being used with considerable success for corrosion control. A thin permanent coating is laid down which protects the pipe from corrosive action of the water. After the scale is laid down, only enough silicate is added to maintain the scale.

Soda ash has been employed for the stabilization of pH.

At most of the posts where threshold conditioning has been installed there has not yet been enough time to determine accurately the results of the treatment. However, on those which have been in operation for some time, very encouraging results have been obtained.

At one post in Colorado, the water was found to be extremely corrosive at low temperatures and highly scale forming when heated. Before threshold treatment was installed there was a considerable "red water" problem. Maintenance of an ample chlorine residual was impossible. Hot-water heaters in the town using water from the same aquifer would completely plug after three to six months' operation. The hardness of the water varied from 670 to 900 ppm. with a calcium content as high as 300 ppm. The following treatment was installed in January 1943: soda ash, 9.6 ppm.; ammonium sulfate, 10 ppm.; sodium hexametaphosphate, 0.5 ppm. In July 1943, there was no evidence of "red water" and only a slight protective scale was found in a section of pipe directly above a hot-water heater. This scale was $\frac{1}{32}$ in. thick and when removed left the metal clear, indicating successful corrosion prevention.

At the post in the Black Hills area, where the carbonaceous-zeolite softening plant is, artesian well water comes out of the ground at a temperature of 138°F., and is cooled after softening. The untreated cooling water laid down a thick scale on the coils, thus decreasing the cooling efficiency of the units. This cooling water is now being treated with a polyphosphate carrying a residual of about 2.6 ppm. and a pH of 8.3. In September 1943, after the treatment had been in operation for six months, these pipes were inspected and it was found that a considerable amount of the scale had disappeared leaving the cooling pipes clear in places. Similar results are experienced with the same treatment in the other cooling unit.

Treatment for Scale Formation

At a post in Minnesota the water after chlorination is being treated with sodium tetraphosphoglucosate. The water has a total soap hardness of 300 ppm. and a carbonate hardness of 316 ppm. The hardness is composed of calcium and magnesium bicarbonates. Scale formation is largely composed of calcium carbonate. The treatment has proven satisfactory in the inhibition of scale formation. One point of interest about this treatment is the fact that a series of tests showed that chlorine residual increased 14 per cent when the phosphoglucosate treatment was taken off.

In general, it may be stated that this threshold conditioning has great value, but much is to be gained from future and more extensive study. It has been found that two waters, almost identical in chemical composition, may vary considerably as regards scale formation and corrosion. As more information is obtained on the subject, more specific and more accurate treatment can be installed to take care of each situation.

Chlorination is a very important feature in safeguarding the potability of Army water supplies. Kessler, Sundstrom and Tomek have outlined the Army's policy concerning chlorination. The Army's policy of chlorination differs from that of most municipal water departments in that a higher residual is carried. There is no great amount of agreement among the authorities as to what constitutes a proper chlorine residual. Experience indicates, however, that a fairly high chlorine residual is needed on Army posts. Distribution systems are continually being altered and extended. Additional hydrants are frequently being installed. Troops often move into a new post before a contractor can sterilize the new water systems properly. Very little complaint is made, however, about chlorination of water and it is doubtful if most of the troops even notice it. The medical department records of water analyses indicate a remarkably small number of non-potable samples. The non-potable findings were promptly investigated and were attributed to collection of samples of a raw water prior to chlorination or localized contamination due to construction work.

Our experience in operating the water supplies at the Army posts in the 7th Service Command has not brought out any new and startling developments. We have now settled down to routine operation and are endeavoring, insofar as is consistent with the production of a potable and dependable water supply, to operate with the minimum use of critical materials and manpower.

Water Department Practices and Regulations

By Melvin P. Hatcher, D. L. Erickson, John C. Detweiler and W. Victor Weir

THE program of the Missouri Valley Section of the American Water Works Association for the meeting held at Des Moines, Iowa, on October 15th and 16th included a panel discussion of certain water department practices and regulations. The discussion was subdivided into several series of questions each dealing with a particular class of policy and regulation problems. As each series of questions was asked, the questions were answered by members of the panel after which discussion from the floor of the convention was invited.

1. Are fire protection services metered? Are fire hydrants permitted on regular metered commercial and industrial services? Do regulations permit regular services to be extended from fire protection services in a manner requiring the shut-off valve on the regular service to be located on the customer's premises?

Lincoln: Services used exclusively for fire protection are not metered. In a few cases in the past fire hydrants have been allowed on regular services, but at the present there is only one such installation. Regulations require that shut-off valves on all services be located on public property; they do not permit regular services to be extended from fire protection services.

St. Louis County: Fire protection services are unmetered. One such service was metered in World War I when a large industrial customer took so much water through a fire line that pressures were noticeably lowered. There is still some water used through this meter which is billed to the customer at regular rates. A few cases of unauthorized use of water through sprinkler system services have been encountered but a phone call to the inspector of the insurance company covering the risk always brings a stop to the practice.

The problem of permitting fire hydrants on regular metered commercial or industrial services appears more academic than practical. Customers having services large enough to support a fire hydrant will generally have separate fire protection services. Customers are permitted to place fire hydrants on metered lines although there

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Summary of a panel discussion presented on Oct. 15 and 16, 1943, at the Missouri Valley Section Meeting A.W.W.A., Des Moines, Iowa, by Melvin P. Hatcher, Dir., Kansas City (Mo.) Water Dept.; D. L. Erickson, Dir., Lincoln (Neb.) Water Dept.; John C. Detweiler, Water Engr., Metropolitan Utilities Dist., Omaha, Neb.; W. Victor Weir, Supt., St. Louis County Water Co., University City, Mo.

is practically no demand for such services; they generally know that the insurance underwriters will give no credit for protection which is limited by the capacity of a compound meter. Moreover, the company zealously insists that the meter be sized for the regular use of water.

Extension of regular services from fire protection services is not permitted. Regulations require that the shut-off valve on each regular service and each fire protection service be located on the right-of-way of a street or upon an easement way so that the shut-off valve can be operated without setting foot on private property.

Omaha: Only a part of fire protection services are metered. Services to automatic sprinkler systems are generally not metered. Services to standpipe connections or to sprinkler systems are metered where there is some chance that water might be used.

Fire hydrants may be installed on regular metered services of adequate size and the rates for such services are based on the number of hydrants. Hydrants on an unmetered fire protection service are sealed and the use of water from such hydrants is not permitted. If the service is completely metered, the customer may use the hydrant for purposes other than fire protection, although such miscellaneous use of fire hydrants is discouraged.

In a few cases regular water services have been extended from fire protection services, although this practice deserves to be discouraged.

Kansas City: Regular fire protection services are not metered. A flat rate of $12 per year is made for each service, regardless of the size. Fire hydrants on regular services are discouraged because of possible damage to meters from high flows; there are, however, a dozen or more such installations in the system at present.

Customers are not permitted to extend regular services from fire protection services in a manner requiring the shut-off to be located on private property or in any way that would cause both services to be shut off by one valve. Exceptions have recently been made to this rule in two cases, however, wherein the customer was able to show that the commercial service would require less critical material if extended from a fire service. In one case the customer made a written agreement to abandon the commercial service after the war and the other customer made a written promise to relocate the commercial service as soon as materials are available.

2. Describe regulations with respect to abandoned services. How long do you allow them to stand idle before shutting them off at the main? Is property owner notified before abandoned services are disconnected?

Lincoln: Abandoned services are not disturbed except in the case of a leak in which case the service is shut off by the department without notice to the owner. The labor involved is charged against the vacant property and the charge is collected from the owner when water service to this lot is again requested. Until they are paid, such charges, like other charges for water or services, become a lien against the property served.

St. Louis County: Abandoned services, such as those to houses which have burned down or have been demolished, are generally left for a period of from two to five years. If, in that time, nothing has occurred to indicate a likelihood that the service

will be used again and if the owner cannot be located for a statement of his intentions, the service is killed at the tap.

Where a service has been disconnected at the main without the owner's permission, the company bears the cost of reconnecting the service when its use is again desired.

Omaha: Unless an abandoned service develops a leak, that service is disconnected at the main only after a disconnection request has been made by the property owner. If an abandoned service develops a leak, an effort is made to locate the property owner in order that the owner may repair the leak; if the owner cannot be located, the service is disconnected at the main and every reasonable effort is made to notify the owner of the action taken.

Kansas City: The owner is required to disconnect the service at the main when a building is burned, torn down or abandoned unless he will make a written statement that the service will be used within a year. The water department has been rather zealous in its efforts to have services disconnected as soon as possible after becoming unused because of the leakage threat, but owners generally are very reluctant to make the disconnection or to pay its cost. In many cases the work has been done by the water department; collection for this work cannot be enforced because the charge is not a property lien and a large percentage of such charges are, therefore, finally abated.

A relatively new kind of unused service has been encountered in recent years. Inter-connections within adjacent business buildings have caused quite a few services to stand idle. This condition has caused service abandonment practice to be reconsidered. The present tendency is to be concerned with abandoned services only when they develop leaks, then to seek the owner to require the repair and, failing in that, to make the disconnection without cost to the owner.

3. How are services constructed with respect to provision for shut-off and protection against freezing within customers' premises? What type of stop-and-waste valve is required ahead of the meter? Is the customer required to maintain this stop-and-waste valve in serviceable condition?

Lincoln: A curb stop is installed near the curb line on each service. No protection against freezing within the owner's premises is required. The service is brought into the basement just above the floor line, a standard globe valve with manually-operated waste valve is required just ahead of the meter and a standard globe valve is placed on the outlet side of the meter. The customer is required to maintain the stop-and-waste valve in serviceable condition.

St. Louis County: The St. Louis County Plumbing Code (provided for by an enactment of the state legislature) requires a T-head stop cock in the street between the sidewalk and the curb and a stop-and-waste valve just inside the basement wall. Either a lever-handle plug type or wheel-operated compression type stop-and-waste valve is permitted, although the latter is now used almost exclusively.

The customer is required to maintain both the curb stop and basement stop-and-waste valve in serviceable condition. Customers quite often object to maintaining any part of the service between the main and the meter but a courteous explanation of the functions of the valves generally causes

the customer to make repairs or replacements when needed.

Omaha: The service is provided with a curb stop near the curb line and a stop-and-waste valve inside the basement wall. The customer is urged to keep both of these valves in serviceable condition, but this is not always done. Meter removal operations are inconvenienced somewhat by the failure of the customer to keep the basement stop-and-waste in proper condition; in these circumstances the customer is required to have the stop-and-waste valve repaired by a plumber.

Kansas City: Services are provided with the customary curb cock at the curb. They enter the house below the basement floor line and are provided with a plug-type stop-and-waste valve below the basement floor operated by a handle extended through a pipe set in the floor. This type of stop-and-waste valve has been found quite unsatisfactory. Roughly 30 to 40 per cent become unserviceable before they are 10 yr. old. In normal times the customer has been required to maintain this valve in serviceable condition. More recently the shortage of plumbing help has caused a revision of this practice. The repair of such valves is not made a condition of continued service; now the customer is merely advised to repair the valve for his own protection.

4. Under what conditions is service provided to houses or buildings under construction? What is the basis of the charge for service during the construction period?

Lincoln: For many years it has been the practice to provide permanent water services and meters in new buildings as soon as possible after construction work started. Because of damages to services and meters in the case of buildings built in the winter, consideration is now being given to the plan of deferring meter installation until the building is ready for occupancy. In this case the property owner or builder will be billed at the minimum rate during the construction period.

St. Louis County: Service to houses under construction is rendered either on a flat rate or metered rate basis. Where sodding is required, it is mandatory that the sprinkling be done at metered rates.

For residence buildings the flat rate for the construction period is 60¢ per room for frame buildings or $1.00 per room for brick buildings. For commercial or industrial structures a metered rate is generally used, although a flat rate is available based on the quantities of concrete, brick, plaster and other building materials required to construct the building. Most large-scale builders prefer to be served at the meter rate, since reasonable care in the use of water will reduce the cost of water service to approximately half the cost of flat rates. Builders of individual dwellings more often prefer the flat rate basis despite its higher cost, partly because they are generally not organized for good control of water usage, and because the flat rate plan relieves them of the expense of providing suitable housing for a meter.

The flat rate is more satisfactory from the water company's point of view for the reason that the expense of reading meters and rendering bills over a construction period, generally covering 4 to 6 mo., is more than the incremental cost of the extra water used under the flat rate.

Omaha: Water service for the entire construction period bears the rate of $2.50 for residential houses of six

rooms or less, with an additional charge of 50¢ for each room for larger houses. Service during the construction period, for commercial or industrial building, is billed at rates based on the quantities of building materials used in constructing the building. No meter is placed in any building until the building is ready for occupancy.

Kansas City: The service is generally run as one of the first construction operations but the meter is not installed until the building it ready for occupancy. Water used during the construction period is sold to the builder at rates which are based on the quantities of building materials used. If the builder wishes to continue with unmetered service beyond the construction period, this service is rendered under a flat rate that has come to be known as a "sodding" permit. This plan of collection for this type of temporary service is burdensome and unsatisfactory for several reasons, and consideration is being given to a charge based on the size of the house. The present plan requires policing to an extent that is entirely disproportionate to the revenue involved.

5. What practice is followed with respect to temporary service of a kind that can be rendered from a fire hydrant? What is the basis of the charge for such service? Is the service metered? Do you permit the customer, under such circumstances, to operate the hydrant?

Lincoln: On payment of a permit fee of $10 per year, the consumer (more often a contractor) is permitted to use water from any hydrant after he has notified the fire department of his intention to use the hydrant, provided the hydrant is operated with a standard hydrant wrench, and provided the flow from the hydrant nozzle is controlled by a manually-operated valve. The consumer is instructed to close the control valve before shutting off the hydrant.

The consumer is permitted to purchase water either at prescribed flat rates, which are based on the quantities of building materials used in the project receiving water service, or at regular metered rates, in which case the consumer places a meter at the hydrant outlet. This meter is read by the department at frequent intervals, depending upon the size of the construction project.

St. Louis County: The use of fire hydrants as the source of a temporary water supply is allowed only in extraordinary cases. All fire hydrants are installed under contracts which provide for the use of hydrants for fire protection or fire drill purposes only. Since the political sub-divisions pay for fire protection on the basis of the number of hydrants, the number is not enough to permit the risk of having a hydrant rendered inoperative by a consumer.

On occasions customers obtain the approval of public officials to use fire hydrants for temporary water service, subject to the final approval by the water company. A counter request, that the public officials absolve the water company from all liability should the hydrant be out of service in case of a fire, has caused practically all such requests to be withdrawn or abandoned.

Omaha: To obtain temporary water service through a fire hydrant, the customer is required to pay a $5.00 license fee and post a $2,500 bond indemnifying the city in case of injury or damage. In addition, the customer is

required to pay for the estimated quantity of water used or for the water registered on a meter set along side the hydrant. Under this plan the customer is provided with a hydrant key and is permitted to operate the hydrant.

To satisfy rather infrequent requests for the use of water for skating ponds in the winter or for truck gardens in the summer, a service has been provided which requires that the water be delivered and that hydrants be operated by water department employees. The charge for this service is $2.50 per hour.

Kansas City: Practice with respect to temporary service from fire hydrants is only fairly consistent and uniform. Considerable attention has been given to the need for a definite workable plan. Present ordinance rates provide for a charge to contractors doing construction work that can be served from hydrants which is based on the quantities of concrete, macadam, stone work and other building materials. Water department rules which the director is empowered to prescribe include one rule of long standing which provides that contractors may be furnished with a fire hydrant wrench for which they are required to make a $50 deposit. The contractor is required thereafter to report and pay for all water used. As would be expected, this practice led to utter lack of control of the use of water through hydrants. In recent years most of the wrenches issued under this rule have been reclaimed.

For the present, when water is to be used from a hydrant, an employee of the water department operates the hydrant. The customer pays a daily rate to cover the cost of such attendance plus the cost of the water either on an estimated or metered consumption basis. This plan has proved reasonably satisfactory.

6. Are services installed by plumbers? If so, are plumbers bonded? What is the amount and scope of the bond? What is the scope of inspectional service applying to customers' services?

Lincoln: The regulations require that servcies be installed at the customers' expense by licensed plumbers operating under a $25,000 bond. The terms of the bond relieve the city of all liability for the work done or for neglect of any kind by the plumber while engaged on public property. In lieu of the bond, the plumber is permitted to carry a public liability and property damage insurance policy endorsed to the city and the general public and providing protection against liability of the scope just defined.

All services, up to and including the meter setting, are inspected by the water department. All water piping beyond the meter is inspected by the city plumbing inspector.

St. Louis County: Services from the main to the customers' premises are installed by plumbers at the customers' expense. State law requires that all plumbers operating in St. Louis County be registered and bonded. The amount of the bond is fixed at $1,000 and is for the benefit of the county or for injured persons or those whose property has been damaged by any violation of the provisions of the Plumbing Code.

The Plumbing Code, authorized by state statute, creates a board of plumbing supervisors who appoint plumbing inspectors. The company has no part in the inspection of service work done by plumbers. Plumbers also inspect the main taps and the services.

Omaha: All water services are installed at the customers' expense by licensed plumbers who are bonded to the city in the amount of $1,000. The bond binds the plumber to proper performance of his work and protects the city against any liability for any injuries or damages growing out of his work on public property.

The water department's inspectional service covers the materials used in the service, the depth of cover and proper installation up to and including the meter setting.

Kansas City: Services are installed by licensed plumbers at the customers' expense. The plumber is required to maintain a bond in the amount of $5,000 which binds the plumber to compliance with water department rules and regulations regarding turning water on and off, and to payment of any bills due the city, and protects the city against any loss or damage occasioned by the plumber's work on public property. As it may have been called to the attention of other water departments, it should be noted that the bond does not cover poor or improper workmanship on the customers' premises. In a few cases this department has been appealed to for the correction of faulty work by the plumber. Moral suasion has helped to settle some such cases.

The water department inspection includes the service up to and including the meter setting.

7. Does the water department or plumber install meters? Does the customer or the water department own the meters? Does the the customer or the water department pay for meter repairs? Do regulations insist on a check valve between meter and hot water heater to protect meter against damage by hot water? On what basis are meters removed from service for test and repair; periodically, or when damaged, or when there is evidence of improper registration?

Lincoln: All meters on new services are installed by licensed plumbers. All new meters on either new or old services are paid for by the property owners and remain their property. All meters are purchased from the water department; this plan assures water department control of the type of meter installed.

All meter repairs are made by the water department. The labor for meter repairs is furnished by the water department without cost to the consumer, but the property owner is charged with the actual cost of the materials required for meter repair.

It has not been the practice to insist on check valves being installed between the meter and the hot water heater. However, such installations are recommended to protect the meter.

Meters smaller than 1 in. in size are checked only where there is evidence of improper registration. All meters 1 to 3 in. in size are checked at least once every five years. Meters 3 in. and larger are checked annually. In addition, all meters, regardless of size, are checked when readings indicate improper registration.

St. Louis County: All meters are owned and installed by the company. Ordinary wear-and-tear repair costs are borne by the company but the customer is charged for repairs of damage resulting from customer neglect, as in the case of damage from freezing or from hot water.

A check valve between the meter and a hot water heater is not insisted upon

or even recommended. If the customer raises the point, he is cautioned that if a check valve is installed a pressure relief valve also must be provided as protection against the development of dangerous steam pressures in the hot water system due to the lack of or failure of temperature controls. A fusible plug between the meter and the heater seems to provide a safer protection against damage to the meter by hot water.

Meters are removed from service when premises are left vacant, when the meter has stopped registering or, periodically, when a meter has registered a fixed amount of water or has been in service for a stated period of years, each as defined by regulations of the public service commission of the state.

The ⅝-in. meters are removed periodically after seven years of service or after having registered 100,000 cu.ft. of water. Larger meters are removed at more frequent intervals; the period between removals from service for 6- and 8-in. meters for instance, is two years. The practice with respect to intervals or quantities metered between tests is such that accuracies on meters removed from service are generally acceptable.

Meters are seldom removed for test solely on the basis of a customer's contention that registration is in excess of actual consumption. In nearly all cases it will develop that consumption is high and that the meter is registering accurately. If the meter is replaced and consumption returns to the customer's conception of a normal bill, as it generally will, the customer can seldom be persuaded that the original meter was accurate.

Omaha: Meters are installed by the water department. The customer provides the meter for service at a new location, but the meters below 1½-in. in size are maintained thereafter by the water department, except in the case of damage resulting from customer neglect such as that due to freezing or hot water. Maintenance and repair work on meters of 1½-in. and larger in size is done by the department and charged to the customer.

Regulations do not require a check valve between the hot water heater and the meter.

Water meters are not removed periodically; they are removed only when there is evidence of damage either by freezing or by hot water or when there is other evidence of improper registration.

Kansas City: All meters are installed by the water department.

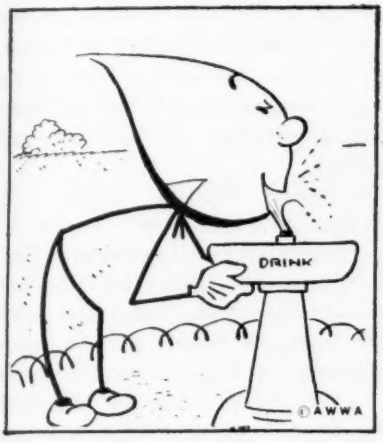
Until recently most water meters were owned by the customers. Prior to 1941 the city owned about 25,000 meters, acquired years ago, out of a total of about 85,000 meters. In 1941 the water department initiated a transfer-of-ownership plan which provided that the city would repair city-owned meters, up to and including 1-inch in size, without cost to the customer and then it would replace city-owned meters when they could no longer be repaired. The plan included the offer of the city to accept ownership to any customer-owned meter.

The plan operates then in this manner: when a meter is repaired, the repair bill is sent to the customer accompanied by an explanation of the plan, including the offer of repair charge abatement if the meter title is transferred to the city. A transfer-of-ownership form is likewise provided. About 12,000 meters have been acquired in this manner and the plan is regarded as successful even though it

brings about higher operating costs for the meter division.

Regulations do not require a check valve in the supply line to heaters. When the subject is raised by the customer, the idea is discouraged.

An effort is made to check meters 3-in. and larger about once a year, although shortage of manpower has made it impossible to hold rigidly to this plan. Smaller meters are removed for test and repair only when there is evidence of improper registration. When the meter division has found spare time under this plan, it has removed and tested small meters that have not been off the line in about the last five years.



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A New Index for Determining Amount of Calcium Carbonate Scale Formed by a Water

John W. Ryznar

THE purpose of this investigation was to obtain a formula that will give a quantitative index of the amount of calcium carbonate scale that would be formed by a water at any temperature up to 200°F.; and to predict, if possible, the corrosiveness of waters that are non-scale forming. This information was also desired for waters in which inhibitors of the polyphosphate or molecularly dehydrated phosphate type were present.

Scale formation in distribution mains and domestic hot-water heaters is well-known. Difficulties with calcium carbonate deposits are also experienced in various types of cooling equipment among which steam power plant condensers, refinery heat exchangers and condenser boxes, ammonia condensers, air conditioning equipment, engine jackets, blast furnace tuyeres and open-hearth door frames are representative. Scale is also a problem in boiler feed-water heaters, locomotive injectors, and boiler feed-water lines. These, along with many other problems caused by undesirable deposits and incrustations, would make a formula having quantitative significance of great value in predicting the behavior of a water and in recommending the necessary corrective treatment.

The molecularly dehydrated phosphates were studied in this connection because of their ability to stabilize a water, which is normally scale forming, up to a certain point, and thus prevent deposition of $CaCO_3$. It was thought that this quantitative index or formula could be best obtained by using the values and corrections for the different equilibria affecting calcium carbonate solubility.

The factors affecting $CaCO_3$ solubility equilibria have been studied by many investigators. Larson and Buswell (1) in their paper on "Calcium Carbonate Saturation Index and Alkalinity Interpretations" give a good bibliography on this phase of the problem. Prof. W. F. Langelier (2), however, should receive credit for first bringing before the attention of water technologists a general expression which takes into consideration the different readily-determined variables in a water affecting $CaCO_3$ solution or precipitation.

In simplified form and for waters in a pH range of 6.5 to 9.5, Langelier's formula for the pH at which a water is in equilibrium with calcium carbonate is:

$$pH_s = (pK'_2 - pK'_s) + pCa + pAlk$$

A contribution by John W. Ryznar, Research Chemist of National Aluminate Corp., Chicago, Ill.

K'_2 and K'_s are apparent constants computed from the true thermodynamic constants K_2 and K_s, the values of which have been determined. K_2 is the second dissociation constant for carbonic acid, and K_s is the activity product of calcium carbonate. The term $(K_2' - K_s')$ varies with ionic strength, dissolved solids and temperature. *pCa* is equal to the negative logarithm of the calcium ion concentration in mols per liter; *pAlk.* is the negative logarithm of the total alkalinity of the water to methyl orange in terms of titratable equivalents per liter.

Larson and Buswell (1), using more recent data for evaluation of the constants and their variation with temperature and total dissolved solids, express the formula for the pH of calcium carbonate saturation as follows:

$$pH_s = log\frac{K_s}{K_2} - \log(Ca^{++}) - log(alk.) + 9.30 + \frac{2.5\sqrt{u}}{1+5.3\sqrt{u}+5.5}$$

In this equation (Ca^{++}) and $(alk.)$ are expressed in parts per million as Ca and $CaCO_3$, respectively.

The algebraic difference between the actual pH of a sample of water and its calculated pH_s is the measure of the degree of calcium carbonate saturation and has been called the saturation index or:

$$\text{Saturation Index} = \text{Actual pH} - {}^{\bullet}pH_s$$

A plus value for the saturation index indicates a tendency to deposit $CaCO_3$, and a minus value a tendency to dissolve calcium carbonate.

The saturation index is, however, only qualitative and as Langelier emphasized, "the saturation index is an indication of directional tendency and of driving force, but it is in no way a measure of capacity."

The emphasis to date on the application of this information has been for corrosion protection of water mains in municipal water systems. In this respect it has been of benefit to water chemists in determining whether waters (as regards calcium carbonate) are on the scale-forming or corrosive side. The saturation index, however, is not always reliable in predicting this because some waters with a positive index actually may be quite corrosive. This point has been observed and reported by Hoover (3).

One reason for this is the fact that the Langelier index does not indicate how much calcium carbonate will deposit; whether a state of supersaturation will be present which will be great enough to produce a precipitate; and whether it is great enough to give a protective film. This can be seen more clearly by assuming that there are two waters of the following characteristics:

Water (a) at 75°C.; pH_s = 6.0;

actual pH = 6.5;

Saturation Index = + 0.5

Water (b) at 75°C.; pH_s = 10.0;

actual pH = 10.5;

Saturation Index = + 0.5

From the saturation index it might be predicted that both waters would be equally scale forming. Actually, (a) would be scale forming, while water (b) would be quite corrosive.

A pH_s of 6.0 shows that the calcium and total alkalinity of the water must be high, while a pH_s of 10.0 indicates that the calcium and total alkalinity are low. Actually then, in these instances,

the pH_s tells more about the characteristics of a water than does the saturation index. A saturation index of + 0.5 in the case of the above waters, tells nothing of this difference.

In order to eliminate the possibility of misinterpreting a positive saturation index as being non-corrosive or scale forming, a new empirical expression, $2pH_s - pH$, is proposed.

The value obtained by the expressions $2pH_s - pH$ is called the stability index for convenience, and also to differentiate it from the saturation index. This stability index is not only an index of $CaCO_3$ saturation, but is also of quantitative significance. Using this expression, waters are much more accurately typed to determine whether scale formation or corrosion is to be expected.

Experimental data have been correlated with this expression so that a semi-quantitative value can be derived for the amount of calcium carbonate scale that will be formed, and a qualitative estimate can be made to indicate whether serious corrosion may be expected.

Using the waters (a) and (b) described above, the following values would be obtained for the stability index:

	Saturation Index	*Stability Index*
Water (a)	+0.5	+5.5
Water (b)	+0.5	+9.5

Unlike the saturation index for these two waters, the stability indexes are quite different. The stability index will be positive for all waters. Experimental results obtained on various waters indicate that the behavior of natural and treated waters having a stability index of 5.5 will be similar and will give an appreciable amount of calcium carbonate scale.

Waters having a stability index of 9.5, on the other hand, will form only a limited amount of calcium carbonate scale and may be severely corrosive, especially at higher temperatures.

The effect of a molecularly dehydrated phosphate (of the formula $Na_6P_7O_{22}$) on the stability index of a water was studied. The molecularly dehydrated polyphosphates have the ability of stabilizing an otherwise unstable water. In the presence of small amounts of these phosphates, a water that would ordinarily form a heavy deposit of $CaCO_3$ remains stable for extended periods of time. The mechanism of this action has been studied by Buehrer and Reitemeier (4).

Similar phenomena of absorption of various materials on crystal faces with subsequent supersaturation has also been studied and reported by Marc and Wenk (5) and Saylor (6).

Experimental Work

In determining the pH_s or the pH of saturation of a water, the constants and corrections for salinity and temperature as given by Larson and Buswell (1) were used. Although the difference in the final answer between Langelier's values and these is small, it is felt that Larson and Buswell's values are based on more recent and corrected data and should, therefore, be used, inasmuch as neither author based the values of the various corrections on experimental work using natural waters. At higher dissolved solids and temperatures the values were extrapolated using the same formulas as for obtaining pH_s at the lower dissolved solids and temperatures, although it was realized that they may not be entirely correct in this range. No attempt was made to check experimentally, at the higher temperatures and salinity, the

values thus obtained of the constants K'_2 and K'_s.

Experimental tests to determine the amount of scale formed by various waters were made on waters having different $2pH_s - pH$ values and on different waters having similar $2pH_s - pH$ values.

The equipment for carrying out these tests is shown in Figs. 1 and 2. Figure 1 shows the arrangement of the apparatus for determining quantitatively the amount of scale deposited by any water under given conditions. In the tests reported, the water was passed only once through the system. Figure 2 shows a line diagram of the equipment in Fig. 1. The different parts of the apparatus are: A, feedwater; B, constant head device; C, capillary constriction; D, weighed glass coil; E, constant temperature bath; F, thermometer; and G, effluent water container.

Two tests were made simultaneously in each constant temperature bath. The coils were carefully cleaned, dried and weighed before and after each test to determine the amount of scale deposited from the water.

Pictures of clean and scaled coils are shown in Fig. 3. The scaled coil shows progressively greater amounts of deposit on the coil as the temperature of the water passing through increases from room temperature to the effluent temperature desired.

The constant temperature baths could be adjusted to give an effluent temperature of the water from room temperature to the boiling point at any desired flow rate. The tests reported here were made at effluent temperatures of 120°F., 160°F. and 200°F. Ordinarily, the temperatures of the effluent water did not vary by more than ± 2°F. All tests were of two-hours' duration with a flow rate of 1 gal. per hr.

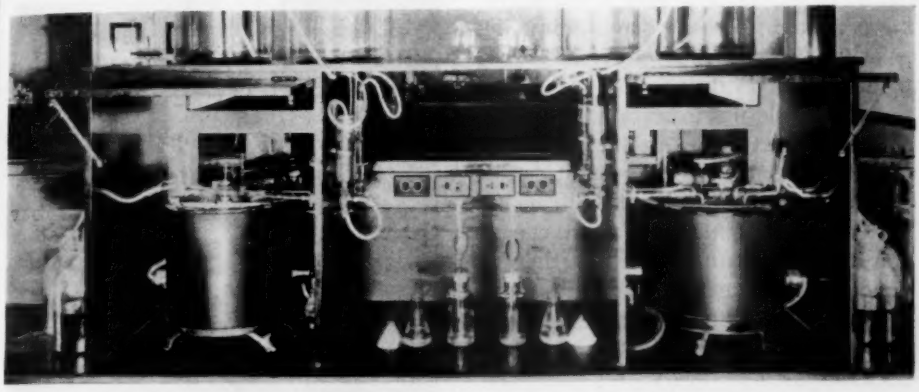

FIG. 1. Experimental Equipment for Study of Elimination of Water System Deposits

The apparatus described above has been used in the laboratory for several years, and gives results that can be easily duplicated and reproduced.

Table I that follows, gives the error that can be expected in the weights of deposits on identical tests.

The coils at the end of a test are rinsed carefully with distilled water to wash out loose sludge. No doubt, by this procedure, small amounts of ad-

TABLE 1

Weight of Deposit in Coil—mg.	*Experimental variation —mg.*
0–5	±0 to 1
5–15	±1 to 3
15–30	±3 to 5
30–100	±5 to 10
100–200	±10 to 20
200–400	±20 to 40

hering scale may be loosened and washed out and account for the above variations.

The incrustation obtained in these glass coils has been checked with field results. Good correlation has been obtained in all cases, so that a water giving a certain number of milligrams deposit can be predicted either as giving trouble-free conditions or an objectionable scale in a certain length of time. For example, in the treatment of feed water on locomotives, it can be predicted whether difficulty will be experienced with injectors with certain waters and treatment, or whether no deposits will form. This permits rapid recommendation of the proper stabilizing or corrective treatment where necessary.

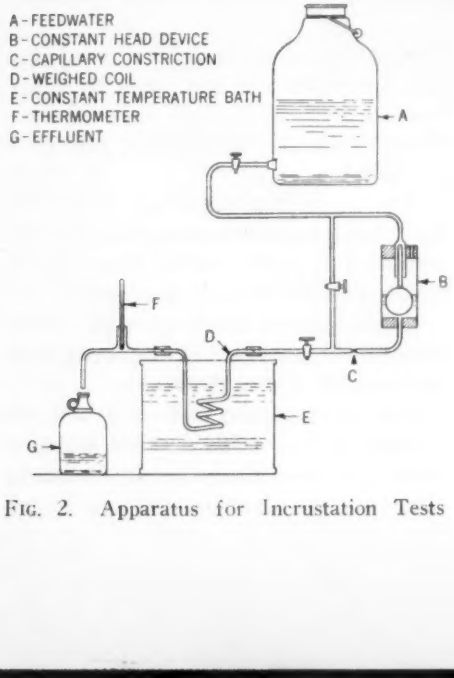

FIG. 2. Apparatus for Incrustation Tests

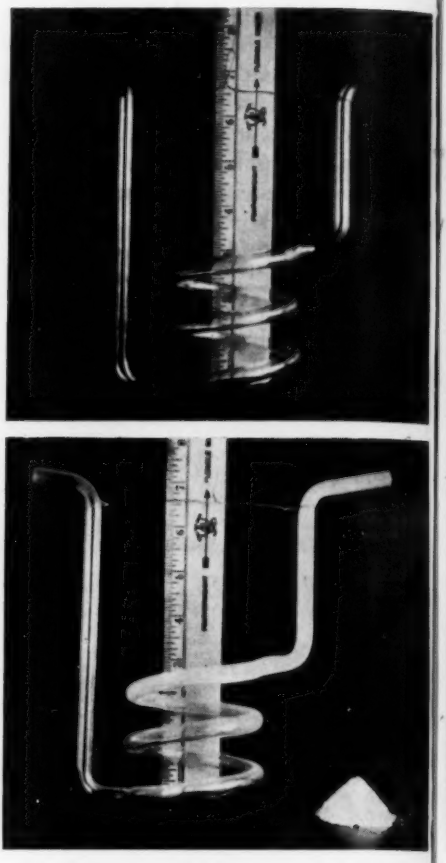

FIG. 3. Glass Coils Used in Incrustation Tests. *Top,* Clean Coil; *Bottom,* Scaled Coil

In Table 2 are tabulated the results of a number of incrustation tests on various waters. In most cases additional sodium carbonate has been used to increase the scale-forming tendency. In these cases, the sodium carbonate was added and the incrustation test started at once. A series of tests are also given in which the Na_2CO_3 was allowed to react one-half hour before the test was started. The pH was determined at the beginning of a test on a sample at room temperature

with a Coleman (style 200) glass electrode.

The calcium and total hardness were determined on the water by the usual soap titration method, alkalinity was determined by titration to methyl orange with N/50 sulfuric acid. Dissolved solids were determined gravimetrically on the raw natural waters. Where sodium carbonate was added, the increase in total solids was calculated. The total dissolved solids were not determined gravimetrically in all cases, because the correction in pH_s due to these solids is quite small. The pH_s was calculated for the temperature at which the test was run.

The results on incrustation from Table 2 are plotted against the stability index ($2pH_s - pH$) and this is shown in Fig. 4. From this graph it is evident that, without stabilizing treatment, a water having a stability index of approximately 6.0 or less is defi-

TABLE 2

Incrustation Tests

Test Started Immediately when Sodium Carbonate Added

Test No.	Water Analysis in ppm.							pH	Temp. of Test °F.	pH_s	Stability Index $2pH_s - pH$	Incrustation—*mg.*	
	H as $CaCO_3$	Ca as $CaCO_3$	Mg as $CaCO_3$	M Alk. as $CaCO_3$	Cl as NaCl	SO_2 as Na_2SO_4	Total Solids					Blank No Treatment	1.7 ppm. $Na_4P_2O_7$ Added to Water
1	114	72	42	103	1.7	29	163	7.90	200	6.89	5.68	0	0
2	114	72	42	132	1.7	29	190	9.10	200	6.79	4.48	36	2
3	114	72	42	183	1.7	29	240	9.50	200	6.65	3.80	105	3
4	114	72	42	68	1.7	71	160	6.70	200	7.07	7.44	0	0
5	155	70	85	169	13.5	188	380	9.70	200	6.73	3.76	95	6
6	155	70	85	264	13.5	188	490	9.90	200	6.55	3.20	147	
7	155	70	85	241	13.5	188	470	9.75	120	7.25	4.75		0.0
8	232	150	82	246	6.8	120	380	8.90	200	6.24	3.58	117	5
9	232	150	82	280	6.8	120	420	9.20	200	6.18	3.16	130	22
10	232	150	82	246	6.8	120	380	9.00	160	6.55	4.10		0
11	215	152	63	298	8.0	85	390	9.30	200	6.14	2.98		77
12	232	150	82	324	6.8	120	460	9.30	160	6.46	3.62		5
13	232	150	82	324	6.8	120	460	9.10	160	6.46	3.82	66	
14	304	133	171	130	25.5	386	410	7.65	200	6.55	5.45	4	0
15	304	133	171	322	25.5	386	760	9.70	200	6.19	2.68	183	202
16	304	133	171	390	25.5	386	830	9.82	200	6.12	2.42		253
17	304	133	171	322	25.5	386	760	9.70	120	6.85	4.00		0.5
18	465	301	164	350	13.7	200	550	7.25	200	5.86	4.47	55	0
19	465	301	164	472	13.7	200	630	8.65	200	5.71	2.77	325	124
20	465	301	164	535	13.7	200	690	8.90	200	5.68	2.46	405	280
21	465	301	164	470	13.7	200	630	8.60	160	6.07	3.54	119	5
22	465	301	164	470	13.7	200	630	8.55	120	6.35	4.15	74	
23	465	301	164	470	13.7	200	630	8.60	120	6.35	4.10		0
24	465	301	164	550	13.7	200	700	8.90	120	6.33	3.76	93	12
25	430	304	126	530	15.4	190	740	7.30	200	5.63	3.96		5.5
Waters reacted 30 min. after sodium carbonate added—then test started and water analyzed													
26	108	66	42	135	10.2	20.4	170	8.75	200	6.80	4.85	53	
27	109	61	48	137	10.2	20.4	170	8.70	120	7.49	6.28	4	
28	120	68	52	142	10.2	20.4	185	8.70	160	7.12	5.54	15	
29	110	65	45	200	10.2	20.4	240	8.95	200	6.62	4.29		4
30	208	137	71	260	8.5	96	370	9.00	160	6.58	4.16		0
31	226	157	69	328	8.5	96	440	8.80	120	6.75	4.70		0
32	260	137	123	280	8.5	96	390	8.55	120	6.88	5.21	35	
33	312	143	169	328	25.6	368	720	9.40	120	6.81	4.22		0.5
34	405	260	145	440	15.4	190	650	8.75	160	6.11	3.47		20
35	415	260	155	520	15.4	190	730	9.10	200	5.69	2.28		339
36	440	302	138	470	15.4	190	680	8.55	120	6.35	4.15		0
37	440	280	160	470	15.4	190	680	8.80	200	5.72	2.64		206

nitely scale forming, while an index above 7.0 may not give a protective coating of calcium carbonate scale. Corrosion would become an increasingly greater problem as the stability index increased to above 7.5 or 8.0.

With stabilizing treatment, on the other hand, in this case use of a polyphosphate of the formula $Na_9P_7O_{22}$, a water with a stability index as low as 4.0 can be used at temperatures up to 200°F. with little danger of scale formation. Inasmuch as these phosphates also have definite corrosion inhibiting powers, a water with a stability index around 7.0 to 8.5 may be profitably treated with these phosphates. Tests are now being made to determine more exactly the type and amount of treatment required for corrosion protection for waters of varying stability indexes in the corrosive range.

On the basis of the two curves in Fig. 4, and as good approximations, the amount of incrustation that will be formed by a water with a particular stability index can be calculated as follows:

For limits of stability index between 2 and 7, with no treatment:

$$\text{mg. incrustation} = \frac{44{,}700}{(2pH_s - pH)^{4.73}}$$

For limits of stability index between 2 and 4, with 1.7 ppm. of $Na_9P_7O_{22}$:

$$\text{mg. incrustation} = \frac{631{,}000}{(2pH_s - pH)^{8.65}}$$

Although the points in the curves lie fairly close along the plotted lines, it is not claimed that any and all waters will fit the curves as well. It is quite possible in some cases that the stability index may be low, indicating scaling tendency. Yet, if the alkalinity is due mainly to hydroxyl ion, there would be very little carbonate ion present to give $CaCO_3$. This would be especially true of some lime-soda softened waters. However, it is felt that a water having a stability index of 7.5 or more will not form a protective layer of $CaCO_3$.

Larson and Buswell (1) advise that the pH should be measured at the temperature at which the equation for determining the pH_s is to be applied and to choose the constants for this temperature. In this work the constants were taken for the temperature at which the incrustation tests were made but the pH was measured at room temperature. This was done for several reasons:

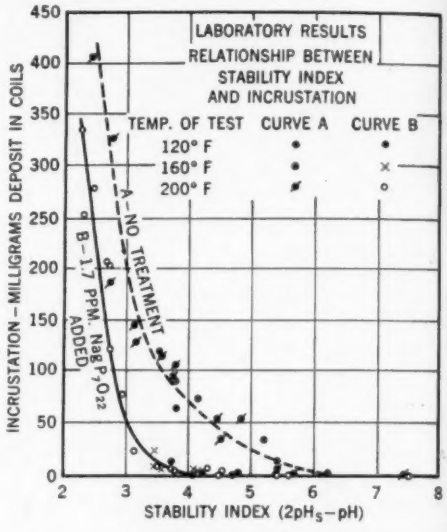

FIG. 4. Laboratory Results Showing Relationship Between Stability Index and Incrustation

(1) It was assumed that the change in pH value of a water with temperature change would be nearly a constant for any particular temperature differential. Since the correlation of the values of the stability index with scale or corrosivity of a water is relative, this change in pH with increase

in temperature would simply shift the values of the stability index to a slightly different figure.

(2) The pH is most easily and accurately measured at room temperature.

(3) The waters dealt with in this paper were predominantly scale forming at the higher test temperatures.

In measuring pH at these higher temperatures, calcium carbonate precipitation would take place with a consequent lowering of the pH. Thus, the saturation index calculated under these conditions might be nearly zero, yet actually so much scale would have formed in the meantime that, in a field installation, a heater coil or injector could become heavily scaled.

Inasmuch as such good correlation was obtained between the stability index and the amount of deposit for waters widely different in total alkalinity, it is felt that it is better to measure the pH at or near room temperature (22°C.) and to use the constants for the higher projected temperature in the calculation of the pH of saturation in order to predict the behavior of the water at that temperature.

To determine how the laboratory results compare with field results, a number of cases were taken at random, both from published literature and from our files, in which the analyses of the waters were complete and the history of the behavior of the water known. These are listed in Table 3. The values for pH_s were calculated, using the formula of Larson and Buswell.

In most of the cases given in Table 3, very little information is present in the literature regarding the condition of the cold-water mains. In most cases, the stability index indicates a corrosive tendency to be present. Of course, the reactions in the cold may be slow and escape notice, but it is felt that tuberculation due to corrosion has in too many cases been taken in a matter-of-fact way as something to be expected. Wilson's discussion (7) of the condition of water mains in typical American cities and the report of the N.E. W.W.A. Committee (8) on pipeline friction coefficients and the effect of age thereon, are of interest in this connection. The N.E.W.W.A. report shows that, based on tests of 473 pipelines in 19 different systems, the average loss in capacity of tar-coated cast-iron pipe, after 30 yr. of service, was 52 per cent. Small mains carrying active water may lose over 60 per cent of their capacity in this length of time. This represents a serious economic loss. Although tuberculation due to corrosion is the most frequent cause of loss of flow due to increased friction, in certain cases this could be due to incrustation formed by an unstable water. Flow capacity losses due to corrosion and incrustation were measured and are shown in the data by Hale (9) taken from a series of large-scale experiments on Catskill water to which varied amounts of lime had been added. These data check very well with the results that would be predicted from Fig. 4 of this paper. It is interesting that corrosion, but no scale, was present in the tests with 13 and 23 ppm. of added lime, although the Langelier index is + 0.5 and + 1.18 respectively at 59°F.; and + 1.25 and + 1.94 at 150°F., at which temperature the tests on hot water were made.

The experimental work of Hale (10) shows a very definite increase in the flow capacity as the water was rendered less corrosive by increasing the dosage of lime and increasing the supersaturation of calcium carbonate.

The data obtained by the N.E.W. W.A. Committee indicated that, all

TABLE 3

Behavior of Waters with Different Stability Indexes in Field

No.	City or Plant	Water Analysis in ppm.							Actual pH	Temp. °F.	pH_s	Stability Index $2pH_s - pH$	Remarks
		H	Ca	Mg	M	Cl as NaCl	SO_4 as Na_2SO_4	Total Solids					
		as $CaCO_3$											
1	La Grange, Ill. Well water	852	526	326	397	85	666	1160	6.8	59 140	6.72 6.03	6.62 5.26	Heavy scale in heaters, coils etc.
2	Above water lime-zeolite softened	84	43	41	38	34	615	730	8.3	59 140	9.00 8.13	9.70 7.96	Severe corrosion and red water
3	La Grange, Ill. pH increased	75	27	48	116	36	640	855	9.3	59 140	8.51 7.83	7.72 6.36	Water stabilized with phosphate—no difficulties experienced
4	Columbus, Ohio [1] Before recarbonation		55		57			275	10.0	59 140	8.47 7.79	6.94 5.58	Scale in mains Scale in heaters
5	Same as No. 4 Early period after recarbonation		57.5		25			275	9.0	59 140	8.82 8.14	8.64 7.28	Red water and corrosion
6	Same as No. 4 Intermediate period		50		35			250	9.1	59 140	8.73 8.05	8.36 7.00	Corrosion
7	Same as No. 4 Present period		52		39			235	9.7	59 140	8.64 7.96	6.58 6.22	Stabilized with phosphate Some scale, some corrosion at very high temp.
8	Dayton, Ohio	380	240	140	277			488	7.3	59 140	7.18 6.65	7.06 6.00	Scale in heater coils
9	Springfield, Ohio	361	230	131	270			476	7.5	59 140	7.18 6.65	6.86 5.80	Scale in heaters
10	Beverly Hills, Calif.[2] Average effluent		65	210				600	7.66	59 140	7.87 7.20	8.08 6.74	Practically no red water complaints
11	East Bay, Calif. Average Mokelumne Supply		11	15				27	9.00	59 140	9.64 8.97	9.88 8.94	234 red water complaints—1935–36
12	Same as No. 11 Lime added		15.5		21			42	9.00	59 140	9.35 8.68	9.70 8.36	32 complaints—1936–37
13	Pasadena * Devils Gate Tunnel		188		367			470	7.32	59 140	7.29 6.62	7.26 5.92	Red water difficulties (*see note*)
14	San Francisco Hetch Hetchy Reservoir		5.5		8			16	7.0	59 140	10.19 9.52	13.38 12.04	Badly corrosive to mains and installations
15	San Mateo, Calif. Reservoir Station 6 6–15–37		35		58			160	7.3	59 140	8.62 7.95	9.94 8.60	Numerous complaints of red water
16	Same as No. 15 Lime added 8–25–37		58		74			170	8.9	59 140	8.30 7.63	7.70 6.36	Complaints greatly reduced
17	San Mateo, Calif. Reservoir Station 7 6–17–37		44		66			110	8.6	59 140	8.45 7.78	8.30 6.96	Complaints practically eliminated
18	Same as No. 17 8–25–37		54		79			130	8.8	59 140	8.29 7.62	7.78 6.44	Lime treatments in use Complaints negligible

[1] Examples 4 to 10 from data by C. P. Hoover, Jour. A.W.A.A., **34**: 1425–45 (1942).

[2] Examples 10 to 19 from data by F. E. De Martini, Jour. A.W.W.A., **30**: 85 (1938).

* No. 13. This water appears to be an exception and it is suggested that red water conditions possibly due to presence of iron or sulfate-reducing bacteria.

TABLE 3—*Continued*

No.	City or Plant	Water Analysis in ppm.							Actual pH	Temp. °F.	pH_s	Stability Index $2pH_s - pH$	Remarks
		H	Ca	Mg	M	Cl as NaCl	SO_4 as Na_2SO_4	Total Solids					
		as $CaCO_3$											
19	Newark, N. Y.[3]		22		24			54	7.0	59 140	9.16 8.49	11.32 9.98	Corrosion of cold water mains 70% loss in carrying capacity in 32–46 yr.
20	New York City [4] Controlled experimental tests on large scale Raw Catskill Supply		10		7			20	6.9	59 150	10.01 9.26	13.12 11.62	Corrosive Very corrosive—about 3.5 times that at lower temp.
21	Above water Plus 4.5 ppm. lime		15		10			25	8.4	59 150	9.66 8.91	10.92 9.42	Corrosive Only slightly less corrosive than raw water
22	Same plus 13 ppm. lime		25		18			35	9.7	59 150	9.20 8.45	8.70 7.20	Corrosive about 1.3 times that at lower temp.
23	Same plus 23 ppm. lime		35		26			45	10.1	59 150	8.92 8.16	7.74 6.22	Slightly less corrosive in cold than No. 22 above No scale but much less corrosive than No. 22 above in hot
24	Same plus 63 ppm. lime		87		59			80	10.3	59 150	8.18 7.43	6.06 4.56	Some scale Heavy $CaCO_3$ scale
25	Same plus 100 ppm. lime		135		98			120	10.7	59 150	7.80 7.05	4.90 3.40	Heavy scale Heavy scale
26	Example 1 [5]	97	46	51	45	120		270	9.6	150	7.90	6.20	Scale in hot water heaters unless stabilized with polyphosphates
27	Example 2	67	36	31	128	17		145	7.10	140	7.96	8.82	Serious corrosion
28	Example 3	308	202	106	252	910		1100	7.30	59	7.33	7.36	Corrosion in cold water lines and feed lines
29	Example 4		65		125			510	7.60	59	8.09	8.58	Corrosion in cold water mains
30	Example 5	72	34	38	19			155	9.70	140	8.43	7.16	Corrosion in hot water heaters
31	Example 6	55	38	17	8			68	7.0	59	9.37	11.74	Corrosion in entire system
32	Example 7	308	205	103	262			336	7.4	140	6.56	5.72	Scale in heaters
33	Example 8		290		265			1100	7.8	140	6.47	5.14	Heavy scale in hot water heaters
34	Chicago tap water	114	72	42	103	1.7	29	163	7.9	59 140	8.06 7.39	8.22 6.88	Very small amount of corrosion in mains Only slight corrosion—water quite stable
35	Highland Park, Mich.[6] pH increased with NaOH	97	67	30	86			120	8.1	59 140	8.16 7.49	8.22 6.88	Very little corrosion apparent Very little scale or corrosion
36	Lake Erie water [7]	120	87	33	87			156	7.6	59 140	8.05 7.38	8.50 7.16	Corrosive

[3] From paper by Wm. G. Banks, Jour. A.W.W.A., **28**: 1348 (1936).
[4] Examples 20 to 26 from data by F. E. Hale, Jour. A.W.W.A., **26**: 1315–47 (1934); *Ibid.* **27**: 1199–1224 (1935). *See also* W. F. Langlier, Jour. A.W.W.A., **28**: 1516–17 (1936).
[5] Examples 26 to 34 taken at random from files of National Aluminate Corp., Chicago, Ill., and represent conditions before corrective treatment applied.
[6] From paper by I. L. Dahljelm, Jour. A.W.W.A., **33**: 286 (1941).
[7] From paper by G. D. Norcom, Jour. A.W.W.A., **30**: 1353 (1938).

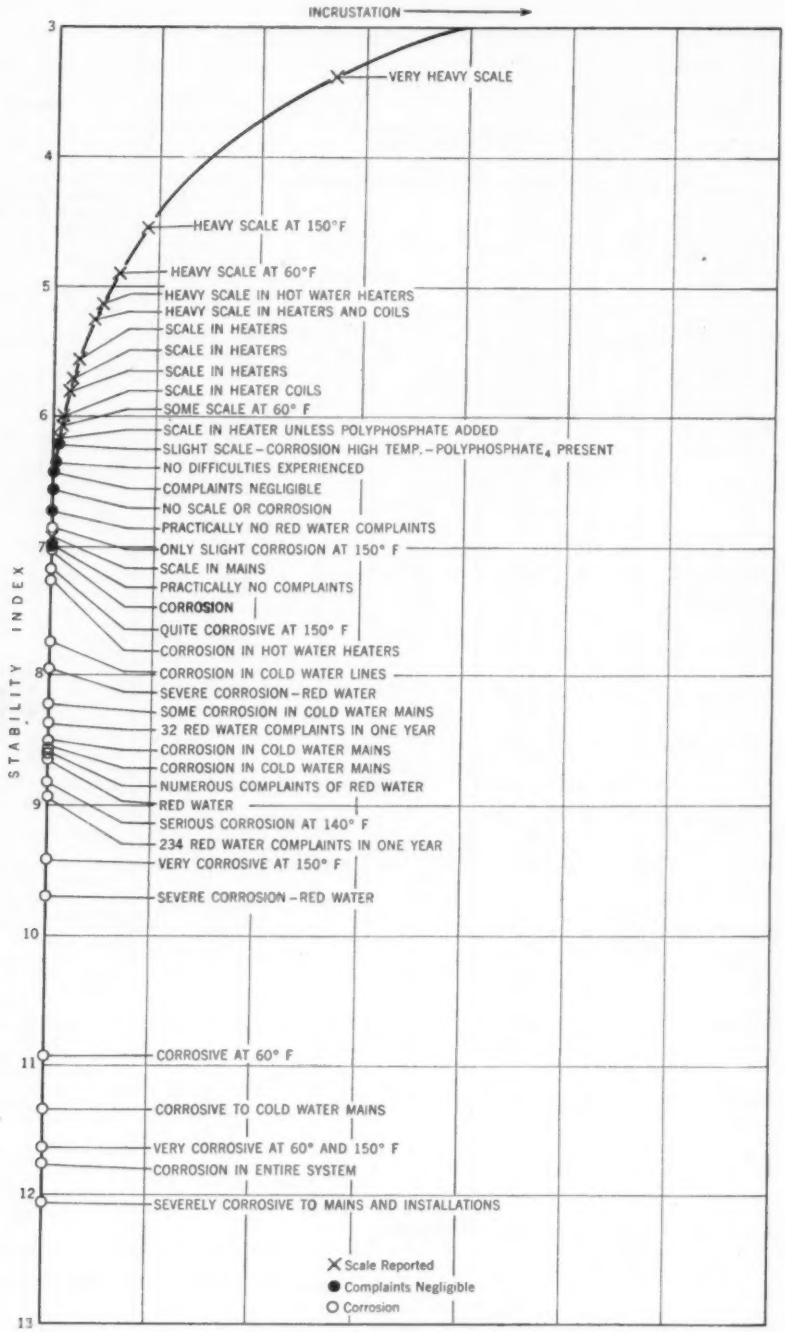

FIG. 5. Field Results Superimposed on Curve A of Fig. 4

factors being equal, there was marked correlation between the pH value of water carried and the rate of capacity loss in the mains. Waters with a pH value of 6.5 gave twice the loss in capacity in a given length of time as those having a pH value of 8.0.

It would appear from the data at hand that a water having a stability index of approximately 6.0 at about 60°F., to which a stabilizing treatment of polyphosphate has been added, should give the best results as regards minimum corrosion and/or scale in the whole system. Under these conditions, corrosiveness due to aggressive carbon dioxide would be near the minimum in most cases.

On the whole, the field data correlate very well with the laboratory results for the different stability indexes. This is shown in Fig. 5 in which the data of Table 3 are superimposed on the curve of Fig. 4. Only those values are plotted where definite information is given for a particular temperature range. It is apparent that with a stability index of 7.5 or higher at 140°F., corrosion is marked. At indexes of 9.0 or higher, corrosion is serious.

It is hoped that the stability index will implement the usefulness of the saturation index, and that it will be of help in predicting more accurately how badly scaling or corrosive a particular water supply may be.

The author wishes to express his appreciation for many helpful suggestions contributed by Dr. P. G. Bird, Director of Research; W. H. Thompson, Director of Service; and J. A. Holmes, Asst. Vice-Pres., all of National Aluminate Corp.

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Discussion

W. F. Langelier *

Especially noteworthy is the author's direct experimental method of estimating the scaling tendencies of water. Unfortunately, the experimental data presented (Table 2) are limited to one type of water characterized by a low pH_s value. It is suggested that the same experimental technique could be

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used to study the corrosive, as well as the scaling, tendencies of waters. In such tests waters would be conducted through a previously scaled and weighed glass coil and the losses in weight noted. If the saturation theory of pipe protection against corrosion is valid, experimental pipe corrosion tests should be run—not in contact with the bare metal, as is customary, but in contact with a material which *has been protected* by the formation of a thin scale.

Mr. Ryznar's quotation to the effect that the saturation index ($pH - pH_s$) is a measure of directional tendency and driving force, but not of capacity, is correct. Although willing to accept the validity and significance of the term, pH_s, he denies that it can be used quantitatively or even qualitatively with waters low in calcium and alkalinity without applying to it an empirical coefficient to which he ascribes a value of two. Since this is the author's main contention and his reason for advocating the use of a new stability index, and since other investigators have misconstrued the exact significance of the saturation index, it would seem that further clarification is desirable.

The saturation index is not a value determined from a sample of water taken from one point in a water system which can be applied to the same water at another point in the system after its character has been modified through deposition or corrosion. This is particularly true of waters of low buffer capacity, i.e., low alkalinity or calcium content. In such waters, the alterations in composition as a result of activity are appreciable, and the saturation index changes markedly as the activity progresses. This, however, does not in itself invalidate the dependability of the index, even with waters of low buffer capacity. It is merely necessary that the sample truly represent the condition of the water at the point in the system where a knowledge of its activity is desired. When the author states that two different waters of the same value may produce scale in the one case and corrode the pipe in another, it should be realized that this inconsistency arises from our inability to determine with sufficient accuracy the precise values of pH_s and pH. Because of this, the writer disagrees with the author's statement that by the simple device of doubling the pH_s value of the water and by reversing signs a new and different index is obtained which possesses greater quantitative significance and which is more accurate in

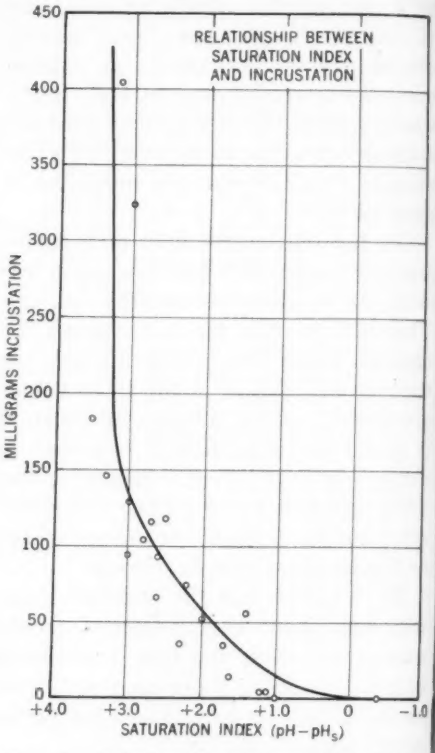


FIG. 6. Relationship Between Saturation Index and Incrustation

typing waters as to corrosive or scaling tendencies.

The essential significance of the hypothetical quantity represented by the term, pH_s, is its constantly changing value with progressive change in analytical character as activity proceeds. The fact that the experimental data which the author presents in Table 3 show that milligrams-of-deposit plot more favorably against the stability index (Curve A, Fig. 4) than against the saturation index (Fig. 6) hardly warrants the conclusions drawn therefrom. Of the tests made, all those yielding significant amounts of incrustation were with waters of high calcium and alkalinity content. The highest pH_s values represented (7.3) limit the conclusions to hard waters of this type. Moreover, in the experimental methods used, at least two significant errors of assumption are made. These relate to (1) the limited time period allowed for the attainment of equilibrium, and (2) the assumption that there is no appreciable error in using the Larson and Buswell constants and neglecting to measure the actual pH at the temperature of the experiment. The assumption that a zero deposition in the experimental test coil, after a detention of two hours, would still be zero under actual water-piping conditions—with holding periods of many hours as well as with continuous operation—is probably subject to appreciable error.

Author's Closure

It has been the object of the author to arrive at a simple, usable index for predicting the behavior of various types of waters at various temperatures.

The errors of assumption mentioned by Prof. Langelier have already been discussed in the above paper.

1. Inasmuch as it has been the object of the work to arrive at a simple usable index, the pH was determined at room temperature for that is the fashion in which most operators and laboratories are set up to run it.

2. The use of the Larson and Buswell constants has been discussed and their limitations noted.

3. The time period allowed for the attainment of equilibrium is deemed to be sufficient. It would appear to reproduce field results quite well, as will be noted by comparing the stability index range between scale and corrosion in Fig. 4 (No Treatment Curve), representing laboratory tests, and Fig. 5, representing field tests. The point of no scale comes very close to the same stability index value in both cases.

Many experimental tests have been made with waters of high pH_s, that is, above 7.5, but in all cases no deposit has been obtained in the coils. These tests were not reported in this paper because it was felt that they fall under a study of corrosion rather than scale formation. As stated before, work is

TABLE 4

Example No.	pH_s	*Actual pH*	*Saturation Index* $pH-pH_s$	*Stability Index* $2pH_s-pH$	*Characteristics of water in system*
9	6.65	7.5	+0.85	5.80	Scale in heaters
17	7.78	8.6	+0.82	6.96	Practically no complaints of corrosion
5	8.14	9.0	+0.86	7.28	Red water and corrosion

now in progress on correlation of corrosion with the stability index.

A study of Fig. 5 shows the gradual change from scaling to the corrosive tendencies with an increase in the stability index. This is not obtained if the characteristics of the waters are plotted against the saturation index.

That the information obtained by the stability index is not related to the saturation index can be seen clearly by examples 5, 9 and 17 of Table 3. Tabulating the information on these waters for 140°F., the results obtained are shown in Table 4.

In the above examples the saturation index is almost identical, although the behavior of the waters is widely different. This difference becomes at once apparent in the stability index for these waters.

Of the 36 examples given in Table 3, taken from actual field reports, corrosion was the main problem in 20 of these cases. Of these 20 cases reporting corrosion, 11 actually show a positive saturation index. This would indicate then that a positive saturation index is no guarantee that corrosion will not be the predominant reaction.

The stability index described by the author differentiates more reliably between these waters and indicates whether the water will be on the scaling or non-scaling side, either in the presence or absence of inhibitors of the polyphosphate type.

Form WPB-2774 Revised

A WAR Production Board administrative letter, dated February 26, 1944, has been issued by J. A. Krug, Director, Office of War Utilities, which relates to WPB–2774 as revised February 21, 1944. (*See* Jour. A.W.W.A., 35: 977, 1509 (1943)).

Principal changes in WPB–2774 as revised are:

(1) Any request for tax amortization privileges on construction projects must be accompanied by an application for Necessity Certificate (Form WPB–3467); the two cannot be filed separately. Authority will not be granted for construction on which tax amortization privileges have been requested, until Application for Necessity Certificate has been approved. Section 1, Item 9, has been included to facilitate the routing of projects.

(2) A section (Section 1, Item 4) relating to manpower requirements for construction projects has been added.

(3) The authorization section has been changed (Section V, Item 5). It provides that abbreviated allotment number U–2, heretofore required only for purchases of controlled materials, must in the future be used on all purchases of material for which preference ratings are assigned, as well as on purchases of controlled material. This identification is required under paragraph (z) CMP Regulation 6 and will aid manufacturers in reporting the use of their products.

In cases where Form WPB–2774 is used to authorize projects to which Utilities Orders assign allotment number U–9, Section V authorization will be modified to assign U–9 (*See* Item 6, Exceptions).

Only *two* sets of exhibits need to be filed with application.

Copies of Revised Form-2774 may be obtained from OWU–Washington, or from WPB Field offices. Hereafter all WPB–2774 applications must be submitted on the revised form.

Abstracts of Water Works Literature

Key: In the reference to the publication in which the abstracted article appears, **34:** 412 (Mar. '42) indicates volume 34, page 412, issue dated March 1942. If the publication is paged by the issue, **34:** 3: 56 (Mar. '42) indicates volume 34, number 3, page 56, issue dated March 1942. Initials following an abstract indicate reproduction, by permission, from periodicals, as follows: *B.H.—Bulletin of Hygiene (British); C.A.—Chemical Abstracts; P.H.E.A.—Public Health Engineering Abstracts; W.P.R.—Water Pollution Research (British); I.M.—Institute of Metals (British).*

DISTRIBUTION SYSTEMS

Notes on Steel Mains and Main Laying. E. F. BLACKBOURN. Wtr. & Wtr. Eng. (Br.) **45:** 101 (Sept. '42); (*Abstracted*, Jour. A.W.W.A. **35:** 523 ('43)). *Discussion. Ibid.* **46:** 16 (Jan. '43). R. W. HALL: Drawback to small-diam. steel mains if too small to allow man to enter to form continuity of lining at joint. Ashes in backfill source of danger and liable to cause pitting of steel. Essential that sides of trench be firmly packed before wt. of backfill taken by top of pipe. Writer found small metal roller more satisfactory than trowel in making good continuity of lining at joint. DAVID LLOYD: Besides thickness required to withstand bursting pressures, extra steel required to withstand superimposed loads of earth and traffic when laid. Operation of welder on welded joints must be carried out on alternating arcs, on circumference, on one swell and then on opposite side to avoid deflection of free pipe. A. K. POLLOCK: Wooden or steel protective drumheads in many cases ripped off in transit. As precaution against corrosion, advisable to pay higher price per cu.yd. for backfilling. May be necessary to test pH of soil and, if unduly acid, material may have to be imported. Writer can recall 3 instances of dilation of steel pipes under test. Dilation caused partly by pressure and partly by temp. rise. HUGH G. RAMSAY: On some work with which writer connected, found that heavy calking required at back of socket in making cold-strip lead joints badly shattered bitumen lining. All joints thereafter made with yarn and lead run. Sheathing of outside joint completed by use of metal mold following std. practice. Lead wire used extensively in North for jointing of large-diam. bitumen-lined pipes. On another job, all joints of "short sleeve inserted" type in which spigot end "belled" out about $\frac{1}{4}$", socket slightly curved and bitumen lining at socket end finishes at point after which spigot laid "home" about $\frac{3}{4}$" from spigot end, leaving space to be filled in with bitumen strip. Where possible sections of main left under pressure from 3 to 4 mo. before internal joints inspected. "Johnson" coupling provides best type of joint for use with bitumen-lined steel pipes as internal joint troubles practically elimd. Damage to large c-i. main by bomb more easily repaired than steel main, because in former damage localized, but, in latter, joints affected for greater distance. F. TATTERSALL. Problem of change in length due to temp. variation not nearly as serious as first appears and not sufficient to justify rejection of welded joints. For large-diam. steel pipes electrically welded joints have definite advantages. More permanent and less subject to deterioration than any other form of joint. Longitudinal tension can be transmitted and anchor blocks unnecessary. Deformation of thin steel pipes less serious. Essential that competent welders be employed. *Author's Reply:* In order that best backfill results may be obtained, adequate working room on each side of pipe necessary. Specifications should state requirements with regard to filling and ramming under pipe. Question of acidity of soil should not arise as bitumen coating, free from cracks and defects, would prevent acid soil, moisture or stray elec. current from affecting steel. Access manholes provided as part of air-valv

connections. No ruling made in specification with regard to permissible leakage under test. Fig. of 4 gpd./mi. for pipes 30–40″ in diam. amts. to one large drop per sec., very difficult to detect. Assumption that increase of size, noted by Pollock, due to dilation difficult to substantiate as it represents increase of approx. 1¼″ in diam. Principal diversity of opinion with regard to jointing methods concerns question of cast-lead versus cold-lead strip. Principal damage due to calking caused by heel of set hitting pipe. Can be largely elimd. by skill on part of jointer and striker. When using run lead, author found considerable amt. of work necessary on lining afterwards and nothing gained in repair of bitumen by using case lead. No difficulty experienced in locating loose or damaged bitumen by light tapping with small hammer. Disadvantage of "Johnson" coupling that each joint makes break in continuity of lining. Appears to be some support for theoretical aspect of stress in long lengths of steel pipes with welded joints, as discussed by Tatterstall. Author strongly deprecates use of gas welding for any form of field pipe joint owing to large amt. of heat brought to bear on surrounding metal and uneven distr. of heat in circumference of joint. *Discussion. Ibid.* **46**: 114 (Mar. '43). A. G. McLellan: Approx. half total length of 43 mi. of 12–27″ main laid in country liable to subsidence due to colliery workings. Decided that pipe should be steel with "Johnson" couplings. Discontinuity of pipe lining at joints appreciated and protection given to exposed metal. Outside of joints protected by molding bitumen around them. Important point in using these joints need for good anchorage at bends and adequate end support. "Johnson" joint expensive although cost of making mitigates against first cost. Pipe bed-making not mentioned in paper, but contractor knows value of good bed-making joint without which well regulated joint not easy to obtain. Choice of bituminous lining will lie between thick "centrifugal" lining or thin "spun" lining, more in nature of pure bitumen. Preparation of pipes to receive lining and sheathing either by shotblasting or pickling should receive consideration in design. With smaller sizes of pipe always doubt about small defects in lining.—*H. E. Babbitt.*

Internally Sleeving a 36-Inch Water Main. Arthur Montague Moon. J. Inst. Civ. Engrs. (Br.) *No.* 3: 194 (Jan. '43). 36″ diam. c-i. main under roadway and at considerable depth under hill sustained extensive damage. Only satisfactory method of repair was to "sleeve" damaged portion with steel tubes using as large a diam. as could be navigated through 36″ main. Most suitable tubes immediately available were "nominal" 30″ bitumen-coated steel pipes, actual od. of 32¼″. Solid jointed tube would not travel through main. Flexible joints obtained through use of butt straps 12″ wide and ⅜″ thick. "Digging in" of butt straps avoided by use of small trolleys running in pipe invert. Trolley also approx. centered sleeve in main. 1½″ grout holes drilled in each tube, tapped and plugged before inserting them. When 17′ of tube inserted, tackle attached and remainder of tube placed (total length 58′8″). Leading trolley removed and main packed as central as possible for jointing. Dry sand and cement, in equal portions, next packed in annular space. Neat cement of putty-like consistency then packed in to approx. depth of 6″, tamped hard and allowed to set solid. Grouting of space between sleeve and main next step. Grout neat cement with sand sprinkling in pourable condition injected under 40–50 psi. pressure. Before closing piece laid, interior of sleeve coated with bituminous paint and allowed to dry hard.—*H. E. Babbitt.*

Tall Rigid-Frame Tower of Reinforced Concrete Supports Big Water Tank. Anon. Concrete **51**: 7: 6 (July '43). 100,000-gal. entirely wood tank supported by rigid-frame tower of reinforced concrete design 115.5′ high. Redwood tank of 36.5′ diam. extends upward 21¼′, surmounted by airplane beacon and lightning arresters. Footings extend 10′ below ground surface. Tower legs braced with rigid-frame struts vertically at 19′ intervals, in vierendeel fashion, and batter from 35′ centers at base to 21¼′ c. to c. of columns at top. Batter gives tower increased lateral stiffness as well as greater stability against overturning, and good architectural motif. In gen., concrete columns 24″ sq., and struts 30″ deep except at platform level, where they are 48″ deep and arranged to support grillage of concrete dunnage beams. Both columns and struts well reinforced in both faces, as required for bending moments and direct loads. Tank consists of 3″ reduced plank floor laid directly on concrete supporting structure, with 3″ vertical redwood stave sidewalls held with ¾″ round circum. steel hoops spaced at variable intervals. Roof supported from side walls and by auxiliary

wooden columns inside resting on floor. Single steel 24″ pipe riser extends from ground to tank on center line of tower, supported horizontally at 19′ intervals by diagonal rods with turnbuckles. These rods also form horizontal lateral systems in each story of tower serving to keep latter squared up under diagonal and quartering wind loads. Constr. quants. involved include: excavation, 107 cu.yd.; concrete, 235 cu.yd.; and steel, 29.5 tons. Painting scheme *International* orange and white.—*Ralph E. Noble.*

Lumsden Pipe-Flange Grinding Machine. ANON. Engineering (Br.) **155:** 207 (March 12, '43). Machine designed primarily for dealing with piping situated in positions of difficult accessibility. Metal-to-metal joint which does not require jointing material most satisfactorily and easily assembled type. Lumsden pipe-flange grinding machine produces steam-tight jointing surface in fraction of time required for hand scraping and needs only semi-skilled labor. Slightly conical form of faces results in load being applied and actual joint formed on area lying inside bolt ring and immediately surrounding bore of pipe. Straight edge placed across flange will show center to be higher than outside periphery by only about 0.0005″ per in. of width of flange. Time for grinding flanges of pipe ranging from 12 to 15″ in diam. is 30 min. Floor space occupied about 12′ × 9′ and weighs about 8 tons.—*H. E. Babbitt.*

Failure of an Entire City Water Supply Due to a Broken Main. Wtr. Supply & Sew. News, Wash. State Bd. Health **7:** 1 (Mar.-Apr. '43). Record of events at town of Tekoa, 45 mi. southeast of Spokane, Wash. 10″ pipeline crossing creek failed because of erosion of creek bottom which washed away pipe foundation. Town out of water for about 18 hr. Fire hose finally used to carry water over creek during emergency. Interesting acct. and narrator draws 3 conclusions: (1) air lines should be provided on deep wells (to measure drawdown) and continuous records kept of water levels at all times; (2) master meters should be provided on all supplies whether pumped or obtained by gravity; (3) all valves in distr. system should be accurately located with respect to fixed points such as hydrants, curbs or telephone poles. Charts, maps or records should be prepd. listing these locations. Valve boxes should be provided and brought up to street grade. Also, valve boxes should be accurately located with respect to fixed points such as hydrants, curbs or telephone poles.—*P.H.E.A.*

Pipe Protection With a Thin Enamel Coat. JOHN J. CROWLEY. Eng. News-Rec. **129:** 28 (July 2, '42). About 9330′ of 44″ steel pipe in San Francisco water system recently reconditioned and relaid with new lining and coating of coal-tar enamel having min. thickness of $\frac{1}{32}$″ instead of usual $\frac{3}{32}$″. Hot-plate process for bonding enamel elimd. necessity of using primer coat. Pipe, made up of steel plates $\frac{1}{4}$ and $\frac{5}{16}$″ thick with 2 welded longitudinal seams, had been laid in 30′ sections with welded bell and spigot joints and had been protected by asphaltic-dip covered with rag-felt wrapping. Pipe hauled in 60′ lengths to yard and there cut into 30′ lengths. Saddles and nipples and all excess weld metal and slag removed, but bell ends of joints left in place for use in relaying. Rag and asphalt coating knocked off pipe readily with 3–4 lb. hammers when temp. below 60°F. Pipe then heated by gas burners while being spun at 8 rpm. and old lining removed with hand scrapers thrust in parallel to pipe axis. When relatively large amt. of heat applied for relatively short time, lining becomes fluid adjacent to pipe and can be peeled off readily. Correct application of heat most important. Heating usually must be repeated 2–3 times. For final clean-up, pipe sprayed with thinner and then hand scrapers, steel wool, wire brushes and rags used, this treatment usually being given twice. Small patches left by rapidly drying thinner removed by spraying and washing with naphtha, followed by use of wire brushes and steel wool. Coal-tar enamel then applied inside and outside after heating pipe to 325°F. Outside coating applied in 2 operations, first being poured on from buckets and spread uniformly with hand-manipulated squeegees held against pipe while it was revolved at 8.7 rpm. Rotation then increased to 95 rpm. and hot enamel introduced for interior lining from full-length trough. Air from 2,000-cfm. blower then directed by canvas duct into one end of pipe and, after about 30 sec., jet of cold water turned on, allowing water to be spread out in spray by air-blast. Wash and ripple marks resulted when blower not used. About 2 min. of such treatment sufficient to reduce pipe temp. to below 200°F. Speed of rotation then reduced to 8.7 rpm. and final outside coat applied by same method as first, bringing

thickness up to $\frac{1}{32}$". Spark-gap flaw detector showed coverage to be good except for occasional pinholes along weld lines, which were corrected by brush coat of enamel. Tests showed lining to range in thickness from $\frac{1}{32}$ to $\frac{5}{64}$" and to avg. $\frac{3}{64}$". About 60% more material used than that theoretically required for min. thickness. Two sections of pipe treated with coal-tar pitch with same penetration as enamel used, i.e., 7 at 77°F., gave good linings, but tendency toward brittleness. A few lab. tests indicated that brittleness might be corrected by increasing penetration to 11–13 at 77°F. Hot-plate method patented by O. G. Goldman, Asst. Supt., San Francisco Water Dept.—*R. E. Thompson.*

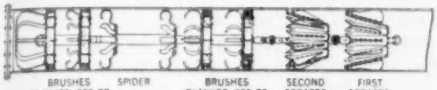
Thin-Sheet Stainless Steel Welded Into Lightweight Water Storage Tanks. ANON. Product Eng. **14:** 622 (Oct. '43). Welding thin-sheet steel for various products and structural members increasingly important to designers. Welding equip. improvements enable production of strong spots and seam welds through close and automatic control of welding temps. and timing. 4½-gal., 4¼-lb. water tank made of 0.016" 18–8 stainless steel all-welded constr. Shotweld system and roller-welding method used on all seams. Ten spotwelds attach hand grip to tank and 2 lugs to filler base plate. Filler first mandrel-formed to desired inside diam. Indirect shot-welding holds diam. during roller seam-welding operation, with $\frac{7}{16}$" overlap. Seam welds consist of 16 overlapping weld spots per in. No calking or soldering needed to make joint water or pressure tight. Filler cap base plate welded in 2 operations described. Tank's exposed edges smoothed and reinforced by flanges rolled over after welding. Curved surfaces throughout improve rigidity and prevent vibration from swash action by carrying half-full tank. Hand grip formed from rectangular sheet-piece without scrap.—*Ralph E. Noble.*

Water Circulating Prevents Freezing. ANON. Western Constr. News **18:** 304 (July '43). Because conditions prevented heating equip. installation, water circulating system installed in 150,000-gal. ellipsoidal-bottomed water tank 80′ above ground at Grand Canyon, Ariz. Tank of dual purpose. Upper 50,000-gal. capac. used for domestic service in various hotel and living accommodations on canyon rim. Remaining 100,000 gal. reserved for fire protection. Tank filled from 6" line also serving as domestic service line with water pumpage approx. 250 gpm. Essential to keep water in 4′ riser of tank free from freezing at all times to supply fire protection sprinkler system. Accomplished by keeping water circulating therein. Suction tee placed at upper end of 6" feeder line with 2½" pipe extending therefrom to within few ft. of riser bottom. Water pumped through inlet pipe at 250 gpm., veloc. in restricted orifice of tee develops enough suction to draw approx. 30 gpm. through 2½" line from riser bottom causing continual circulation throughout length. Temp. tests showed that despite 2" ice layer around shell, circulating system maintd. Continual flow through center, providing water for fire and domestic use continuously.—*Ralph E. Noble.*

How Dawson Keeps Its Water Mains From Freezing. IRVING MCK. REED. Pacific Builder & Engr. **49:** 8: 55 (Aug. '43). Dawson, Yukon Tr., has farthest north successful water system for continuous domestic use and fire protection despite −60°F. temps. Source is water well supplemented by pumping under extra demand from Klondike R. All domestic used water chlorinated. Max. distance pumped 2 mi. and max. height raised 200′. Wood and iron pipes used though former much superior. 6" pipe main tapers to 2", all laid within 2′ of ground surface. Water electrically heated at well. 2 large standby wood-burning boilers in case of power failure. One boiler kept fired during coldest weather and small amt. of steam used to supplement elec. heater. Water temp. at well 36°F. raised to 40–42° by heating plant. Temp. at far end of system 34°F., tested each morning and heat adjusted accordingly. Heat starts in Oct., continuing through cold weather. One 65-hp. elec. pump for domestic purposes. Another used in tandem with first for fire control. For domestic use, pressure 50 psi.; for fire control, 90 psi. In every bldg. and home, ¾" valve kept running to sewer during winter mo. These regulated by company employees only. Sewers never freeze or give trouble. Charge for water and sewer service $10 per mo.—*Ralph E. Noble.*

The Scraping of Large Water Mains. J. F. BAILEY. Wtr. & Wtr. Eng. (Br.) **46:** 317 (Aug. '43). *Discussion. Ibid.* **46:** 378 (Sept. '43). Aqueduct brushed is steel pipe 36" in diam. and 32 mi. long. Periodic scraping of siphons resulted in increase of

27 mgd. (Imp.) in capac. of aqueduct. Scraping assembly shown in fig. (*below.*) Necessary to treat c-i. and steel pipes separately because of rivet heads. Steel pipe sections only brushed. Scraper may be inserted into c-i. pipes: (1) through hatchbox built in pipe; (2) in valve chamber at point where cut and cover section finishes and pipeline commences; or (3) through dowel held in position by "Johnson" couplings. Dowel cut out of pipe provides simple and cheap means of insertion. Lighter to handle than hatchbox and can be dismantled sooner, but when used for extraction purposes scraping assembly stops few yards from it and each portion of assembly has to be uncoupled separately. Time in running scraper small compared with rest of work, as shown by following time table: (1) reduction of water 3 a.m.; (2) shut off main 5:30 a.m.; (3) scraper and brushes inserted noon and withdrawn 7:45 p.m.; and (4) main in service 9 a.m. following day. Results gratifying. At last scraping 3 cu.yd. sludge



removed in 2203 yd. of siphon. Quants. do not take into account lighter particles flushed out during process of emptying siphon. S. G. BARRETT: First recorded occasion, at least in this country, of water main being scraped by hydr. machine in 1866 at Torquay, and machine used was prototype of that illustrated. Factor to be borne in mind when scraping loss of iron from pipe caused by repeated formation and removal of nodules. Scraping no more than palliative. Pipe deposits usually of 2 kinds: (1) rust nodule which contains about 50% iron, and (2) accumulation of silt. Number of machines devised for pipeline scraping in past century. That used by author received general favor. Appears advisable to have brush units spring-loaded on wooden annular rings between iron plates. Recently, in connection with "wet-pipe" scraping of 30″ main, solution of all difficulties probably found. D. LLOYD: Well-known authorities condemned practice of main scraping because of grave disadvantages resulting—life of pipe seriously shortened. Deposits of iron bacteria slime create serious reduction of pipe capac. and, until recently, only possible to remove them by brushing. Means of checking growth of iron bacteria slime are by introducing conditions fatal to growth of organism or removing its food. Killing practicable by heavy chlorination while removal of food appears possible by decreasing H-ion concn. in water. *Author's Closure:* In insertion of assembly into pipe, far more work than in extraction. Time saved in extraction not due to diam. of blades becoming less than original setting through hammer action in pipe. Scraping assembly should never be run through large valves as it damages brass rings. Brushing of mains with present app. proved very efficient. Barrett's suggestion of having brush units spring-loaded on wooden annular ring between iron plates gives room for thought. Scraping of mains indefinitely without relining would certainly shorten life of pipe. Inner surface of pipelines near head works coated with slime due to iron bacteria. Since these siphons not of great length, brushed by hand. On examn., after cleaning, coating showed no marked sign of deterioration. It is in pipes incrusted with rust nodule that pressure scraping app. used. Certain amt. of pitting found, especially in steel pipes coated only and not lined with bituminous lining.—*H. E. Babbitt.*

Re-Using Cast-Iron Pipe at East Chicago, Ind. ALBERT G. VINICK. Cast-Iron Pipe News. **9**: 1: 16 (Jan. '43). E. Chicago Water Dept. salvaging long stretches of 6″ c-i. mains and replacing with new 12″ and 16″ c-i. pipe. Over 1 mi. thus taken up and relaid in other city sections for tying-in dead ends and where consumption small. Early lines laid in 1899, served 43 yr. and good for much longer in new location. Inside free of tubercles, outside in excellent condition. Old lead joints melted out with acetylene torch and lead salvaged. When relaid, pipe joints made with compd. jointing material. All 6″ pipe salvaged except that under paved street. Several large valves recently installed in E. Chicago water system and sections cut from large mains for that purpose show pipe in good condition. For example, out of 30″ Class D c-i. main, installed in '12, was cut 12″ spool with special cutting machine used for installing valves in line under pressure. In another instance, 24″ piece cut from side of 30″ main to install new lateral connection. Pipe in good condition after 30 yr. All work laborious due to fine sandy soil and high ground-water el. Mains installed to have 4′ earth cover, requiring 5′ to 5½′ trench with last 2′ under water. This wet condition requires sand points on most of work.—*Ralph E. Noble.*

ALGAE CONTROL

The Photosynthetic Activities of the Aquatic Plants of Little John Lake, Vilas County, Wis. CHANCEY JUDAY, J. MORRIS BLAIR & E. F. WILDA. Am. Midland Naturalist **30:** 4: 26 (Sept. '43). Phytoplankton photosynthetic activities in Little John L. studied by dropping Hg electrodes and by bottle samples anchored at different depths for different time periods. Mean chlorophyl content of water fell between 7.5 and 19.4 mg./m³. Chlorophyl constituted 0.39–1.06% of dry org. matter in centrifuge plankton. In 4 of 6 series of samples, chlorophyl quant. closely correlated with phytoplankter nos. Phytoplankton O_2 production between 12.5 and 66 kg/ha/da, with glucose equivs. of 8 and 35 kg/ha/da respectively. Total O_2 production from May to Sept., inclusive, estd. at 3274 kg/ha, equiv. to 1745 kg/ha of glucose; being 32 times Aug. centrifuge plankton drop. Significant correlation found between chlorophyl content of water and hourly O_2 production. O_2 consumed quant. ranged from 8 to 3 kg/ha/da while O_2 consumption varied from 48 to 71% of O_2 produced on clear and partly cloudy days, but on cloudy day O_2 produced only 42% of that consumed. Resulting from phytoplankton photosynthetic activities, water of 0.3 stratum became supersatd. with O_2 in July and early Aug. Max. excess 67% above satn. requirement found at 3 m. Aug. 5.—*Ralph E. Noble.*

Some Plankton Relationships in a Small Unpolluted Stream. JAMES B. LACKEY, ELSIE WATTIE, JOHN F. KACHMAR & OLIVER R. PLÁCAK. Am. Midland Naturalist **30:** 403 (Sept. '43). To evaluate indus. wastes, sewage and various drainage effects on biota of streams generally, desirable to know biota of essentially unpold. stream. 4-mi. creek in N.W. Butler and S.W. Preble Counties of Ohio selected and surveyed. Largely subject only to agric. and rural drainage, creek sampled at 4 stations nearly 1 yr. and plankton content identified and counted. Study of certain physico-chem. features suggest stream largely unmodified, abundant in mineral salts and D.O., low in B.O.D. and without environmental extremes. Greatest potential modifying factor believed entrance of treated sewage shown to increase PO_4 content greatly. No great plankton increase followed latter and, by comparison with other studies, appears that very low PO_4 content sufficient for large plankton pop.; that excess exerts little or no influence. Relatively large plankton pop. present within few miles of headwaters, in water not very old. Creek plankton pop. believed to represent "basic" pop., i.e., that expected in small, slightly alk. stream, relatively clear, slow flowing in some stretches, well oxygenated, of low B.O.D. and not subject to extreme poln. of any sort. Comparative stream studies and lab. expts. made to evaluate nitrogen (N)-phosphorus (P) plankton relationships due to admitting large amts. of treated sewage. Evidence of definite biol. cycle for P use noted. Extremely small amts. of P, possibly in excess of amt. often added by sewage, appear sufficient for abundant plankton production. Apparently P excess removed either non-biologically as insol. tricalcium PO_4, or used in bottom film not investigated. As long as P present in ample quants., other food, at least org., used rapidly, but diminishing P below critical point greatly retards use of org. food. Maintg. excess available N and P in adequate light, O_2, small variations of pH, osmotic character, and temp., still failed to maint. or provide "normal stream plankton" in lab.—*Ralph E. Noble.*

My Experiments With Algae Control. W. D. HELD. Beach & Pool **17:** 9: 7 (Sept. '43). Yellow-green algae cause pool trouble. Control substances include chlorine, Ca-hypochlorite, pot. permanganate and $CuSO_4$. Good results obtained by starting control measures early enough to prevent algae growth. As soon as pools filled with water, dose with 8.3 lb. $CuSO_4$ pmg. followed by 4.5 lb. pmg. weekly. Whenever possible, introduce into reception basin and spread through pool by circulating system. Procedure satisfactory for floating algae but not for colony type requiring scrubbing from walls for which steel brushes effective. Bristle brushes impregnated with $CuSO_4$ by soaking 24 hr. in concd. soln. 3 times more effective than untreated brushes. Broadcast sowing of $CuSO_4$ directly upon algae patches requires little labor and leaves residual toxic action on floor effective long after salt dissolved. Disadvantage: pool bottom stained and bathers may pick up poisonous crystals. Noted that pool in shade from over-hanging trees gave more trouble than one in congested urban area. No algae trouble develops until

pool temp. exceeds 70°F. Exptl. tests with 2-lb. quants. of various salts exactly on 2-ft. sq. areas at shallow end showed $CuSO_4$ best algaecide. Chloride of lime next best and completely removed dead algae by oxidation, thus elimg. need for mech. removal. Disadvantage, however, lies in dissolving salt and resulting milky appearance. Rock salt $\frac{1}{10}$ as effective as $CuSO_4$ but worth considering if latter becomes unavailable. Advantage: dissolves readily, does not form ppt. or floc and fairly good algaecide.—*Ralph E. Noble.*

Antifouling Paints. Ind. Eng. Chem. **35:** 432 (Apr. '43). *Test Procedures and General Observations.* G. H. YOUNG, G. W. GERHARDT & W. K. SCHNEIDER: Toxic agents for alleviation of fouling of surfaces immersed in sea water currently thought effective by toxicity, phototropicity—or response of organisms to color, and exfoliation—or "underwater chalking." 3 phases of fouling, somewhat simultaneous, are: formation of a slimy microbiol. film, attachment of microscopic fouling organisms, generally larval, and their maturation to visible forms as barnacles, mollusks, annelids, Bryozoa, algae and other growth. Expts. indicate slime formation may eventually vitiate antifouling paints by preventing lethal concn. of toxic agents from bldg. up at slime film-water interface. Daphnia used as toxicity test object since impractical to maint. colonies of Cypris larvae inland. 3 basic types of org. compds. found outstandingly effective at about 10^{-5} molar were certain *o-* and *p-* substituted phenols and halogenated derivatives, cyclic nitrogen bases of pyridine and quinoline family and certain unsatd. aromatic aldehydes, as cinnamic aldehyde. Mixtures more rapidly lethal than single reagents. In 0.001 *M* solns. of metal chlorides, mercury, copper, zinc and manganese effectively lethal. Equilibrium permeability of vehicle to sea water controlling factor in toxicity; preferred permeability approximates 100 by Wray and Van Horst method. Test panels of grade C cypress and sandblasted steel, exposed to Atlantic Ocean near Daytona Beach, Fla., after 2 or 3 priming coats and a single antifouling coat. Color had no effect on fouling characteristics, but slightly greater growths found in dark areas than in bright sunlight. Authors believe the harder the exposed paint film, the better the protection offered. *Heavy Metal Compounds as Toxic Agents.* G. H. YOUNG & W. K. SCHNEIDER: 2 priming coats on steel, first a phenolic varnish pigmented with zinc tetroxy chromate, second a tung oil-linseed oil coumarone varnish pigmented with red lead followed with heavy metal compds. in oleoresinous short-oil vehicle. Only paints high in metallic copper really effective after several months' exposure. Cuprous oxide showed intermediate antifouling effect. Mercuric oxide appeared specific against marine algae but definitely inferior to cuprous oxide against calcareous shell-depositing organisms. At least 6 lb. per gal. of copper needed for effective antifouling action. Copper arsenite, oxychloride, oleate, linoleate, naphthenate, pentachlorophenate and tetrachlorophenate found ineffective as poisons to shell organisms in antifouling paints, although org. acid salts and phenates showed action against marine algae.—*A. A. Hirsch.*

Copper Sulfate for Aquatic Nuisances. L. F. WARRICK, F. J. MCKEE & A. E. BARTSCH. Pub. Wks. **73:** 9: 21 ('42). Method of applying copper sulfate to lakes for control of algae, etc., used in Wisconsin, as follows: Barrel, which has partition extending from top to within 6" of bottom, placed in boat. Crystals of copper sulfate, about size of peas, put in ½ of barrel, and hot water from cooling system of boat's engine discharged into other half. As water passed under partition, dissolved copper sulfate and almost satd. soln. obtained. This method dissolved about 200 lb. copper sulfate per hr. Water drawn from lake by motor-driven portable pump in boat; small amt. of copper sulfate soln. introduced into suction side of pump. This mixed in pump with comparatively large amt. of lake water and dil. soln. sprayed on surface of lake. Venturi meter installed which measured amt. of copper sulfate soln. entering pump. By insertion of another baffle in barrel found possible to maint. copper sulfate soln. at about satn. point. Amt. of copper sulfate added to lake varied by altering speed of boat and amt. of soln. fed to pump. Expts. conducted to det. effect of copper sulfate on fish. Found that with alky. of 248 ppm. and temp. of 10–11°C., brown-trout fry, 32–50 mm. long, all killed within 28 hr. in water contg. 5–200 ppm. copper sulfate. In another expt. with brown-trout fry, found that in water contg. 25 ppm. copper sulfate all fish died within 2½ hr. when alky. 6 ppm., but some survived after 12½ hr. when alky. 248 ppm. Toxic dose for bass fry, 1–1½ mo. old, in hard water, found

to be 80 ppm. copper sulfate and for older bass 160 ppm. copper sulfate. In hard water to which copper sulfate added, insoluble copper compds. formed and in general most of copper removed from soln. in ½ hr. Therefore, amt. of copper sulfate required to kill fish greater in hard than in soft water and toxic doses given for fish correct only for distd. or very soft water.—*W.P.R.*

Plankton and Its Relationship to Chemical Factors and Environment in White River Canal, Indianapolis, Ind. EUGENE R. HUPP. *Reprint*, Butler Univ. Botan. Studies **6**: Papers 1–8 ('43). Water works would receive useful tool if plankton pulsations could be foretold. Stresses importance of presence of abundance of org. matter to promote algae growth, but disagreement exists among researchers as to what definite chem. and phys. requirements essential. Results of 4-yr. study on water from west fork of White R. reported. Stream contained sewage flashy in character, and in late summer and in low rainfall periods, low and sluggish with many pools. 2 of major pools formed by dams; one used for Indianapolis water supply. In '38, daily tests of total algae, diatoms, D.O., pH, alky., CO_2, hours sunshine, water temp. and rate of stream flow made. During this yr. 4 plankton peaks observed: (1) in late May and early Apr.; (2) in last of June; (3) last of Aug.; and (4) in first part of Oct. (1) and (2) pulses approx. 50% diatoms, with remainder chiefly chlorophyceae; (3) and (4) chiefly diatoms. In season when rainfall variations virtually elimd., plankton peak accompanied by increase in D.O., initial decrease in alky. and pH with both rising during middle of pulse; CO_2 unexpectedly remained fairly const. First and last pulse curves for D.O., pH and CO_2 for this yr. more closely related to diatom curve than to either chlorophyceae or total algae. Alky. and NH_3 curves show no relationship to algae content, but NO_2, NO_3 and silicates usually high preceding plankton pulse and decreased rapidly just before peak reached. NO_2 and NO_3 correlated fairly well with total plankton; silicate correlation good with diatoms. During 4-yr. study, rhythm of plankton pulsations fairly const., diatom pulses usually limited to spring and fall and chlorophyceae more abundant in summer. Vernal peak never occurred at temp. below 10°C. nor autumn peak after water cooled to this temp. Upstream investigations showed increase in plankton where sewage introduced into stream, as natural purif. proceeded plankton decreased. Author concludes decrease in NO_2, NO_3 and silicates might be used as indication of impending plankton pulse represented by diatoms or mixed flora and decrease in only NO_2 and NO_3 with silicates remaining fairly const. would indicate diatoms absent. Numerous comprehensive graphs.—*Martin E. Flentje.*

A Study of the Seasonal Distribution of Plankton in White Rock Lake. MARCILE PATTERSON. Proc. Trans. Texas Acad. Sci. **25**: 72 ('41). Although little correlation could be established between physico-chem. factors and plankton blooms and pulses, observed that rotifers reached peak in March at surface when O and bicarbonates lowest; copepods frequented depths where O high and bicarbonates low; nauplii most abundant in May at 6 m., where O lowest from Dec. to June; cladocerans frequented lower levels, probably because they are photoneg.; phytoplankters usually most abundant at depths where O values highest.—*C.A.*

STREAM POLLUTION AND ITS CONTROL

Stream Pollution. G. G. FASSNACHT. Monthly Bul. Ind. State Bd. Health **47**: 206 (Sept. '43). Stream poln. relative condition detd. by use-demand. Latter provides 4 gen. stream classifications: (1) Exclusively for rough indus. purposes or irrigation. Satisfactory if free from sight and odor nuisances. (2) For fishing. Definite quants. of D.O. must be maintd., toxic gases and salts held to low concn. and low temps. and turbidities desirable. (3) For bathing and recreation, greater purity required than for fishing. (4) For drinking after chlorination. Must be devoid of sewage, have chem. concns. acceptable according to stds. and coliform index not more than 50 per 100 ml. Gen. effect of domestic and indus. wastes on streams explained technically. Trade wastes may be toxic or org. types, their B.O.D. and pop. equivs. cited. Deg. of poln. contributed by given waste detd.

by its strength and vol. Streams may be grossly pold. without contg. many typhoid germs, or appear clear, bright and sparkling and contain many pathogenic bacteria.—*Ralph E. Noble.*

Studies in Stream Pollution. G. A. H. BURN. Eng. Cont. Rec. **56:** 14: 50 (Apr. 7, '43). Discussion of stream poln., self-purif. of water, methods of abating poln. and classification of natural waters in regard to use. Stds. of qual. adopted for water for drinking purposes (before and after purif.), bathing, irrigation and maint. of fish life reviewed. Emphasized that present and proposed future uses of water must be considered when formulating limiting std. of poln. No single std. universally applicable.—*R. E. Thompson.*

Practical Planning for Pollution Abatement. C. J. VELZ. N.J. Pub. Health News **26:** 285 (Aug. '43). Successfully utilized approaches to indus. waste disposal in order of application: (1) Systematic study of indus. process by industry itself with view to altering process, elimg. or reducing vol. and strength of waste, salvaging byproducts at profit and protecting natural water resources. (2) Integrate into munic. system and treat centrally with munic. sewage those wastes unelimd. and inevitable byproduct of indus. activity. (3) Provide prelim. treatment at industry prior to discharge into sewerage system, with ultimate disposal through munic. treatment works, where economy and operating technicalities require, e.g., removal of excessive suspended matter by screening. (4) Provide individual indus. waste treatment plants at site where, due to remoteness of indus. or nature of waste, latter not treatable by munic. works. Such instances few. Most indus. wastes can be routed through munic. system. Cardinal principle that future practical planning for poln. abatement must consider all poln., indus. as well as munic. Where economic constr. and operation show advantage to adjoining municipalities co-operatively to build joint works for common problem in common service area, irrespective of political boundary lines, such integration should be developed. Examples cited. 2 methods for joint co-op. developed and effected in N.J: (1) Joint meeting whereby communities mutually agree to construct and operate joint works, each contributing for first costs proportional to waste contribution; joint project administered by community representatives; joint works remaining property of communities and subject to policies detd. by representatives in joint meeting. (2) Through special legislation, definite district prescribed and authority created with powers to construct and operate works. Authority owns and operates treatment plant and intercepting sewers, charging operating costs to municipalities proportional to contributed sewage. In gen., authority method applicable to large areas involving many drainage dists., while joint meeting admirably suited for smaller ones. Third factor in practical planning for poln. abatement is coordinated action by all drainage basins with emphasis on stream for max. utility consistent with all reasonable uses. Only return from waste treatment works is value of clean, usable stream. Kind of poln. abatement program needed in each given drainage area detd. primarily by intended use of each watercourse. 4 gen. legitimate uses and illegitimate fifth: (1) potable supplies; (2) market fish cultivation; (3) recreation and bathing; (4) navigation, indus. supplies, etc.; and (5) heavy poln. to extent D.O. approaches exhaustion during low runoff and warm weather. Above problems cannot be solved by local community alone or by remote govtl. agency alone. Require co-ordinated efforts of natl., state and local govts., drawing upon all available knowledge and resources, utilizing machinery for purpose provided through leadership of Natl. Resources Planning Bd.'s sanitation subcommittee for N.Y.–N.J. Coastal and Lower Hudson Drainage Basin, composed of natl., state and local representatives directly interested in sanitation. Com. objective oriented to solve problems discussed above. To achieve them, practical planning must include field investigational and promotional work. While supporting funds must be made available, money alone will not assure successful program. Latter depends also upon will and determination to achieve in minds of cons. engrs., sewage treatment plant supts., pub. officials and industrialists.—*Ralph E. Noble.*

Stream Pollution Abatement to Cost a Billion Dollars. *Vast Postwar Program Requires Planning Today.* ABEL WOLMAN. Sew. Wks. Eng. **14:** 135 (Mar. '43). Among many worthwhile remarks, author referred to forthcoming report of Ohio R. poln. survey which will indicate in that drainage basin alone approx. $200,000,000 of sewage treatment, pub. and private, waits accomplishment, representing requirements of 20 million

people. Applying similar figures to U.S. urban pop., program for private and pub. stream poln. abatement approaches approx. $1,000,000,000.—*Ralph E. Noble.*

History of Stream Pollution in Indiana. THURMAN B. RICE. Monthly Bul. Ind. State Bd. Health **47**: 201 (Sept. '43). Stream poln. unimportant until 1890 when strawboard waste appeared in Mississinewa, White, Blue and other rivers, precipitating first lawsuit by *Ind. Water Co.* v. *Am. Strawboard Co.* about same time oil and gas waste pold. Wabash, Salamonie, Mississinewa, White and other rivers. Later, sewage, artificial gas plants, slaughterhouse, acid from iron galvanizing plants and other wastes developed. By 1900, problem serious. Stream poln. bill of '01 passed to improve situation. Actually made it worse because holder of state stream poln. permit could legally discharge into stream any waste desired without being liable in any suit or equity. Act repealed in '09. Until '17 most streams reduced to status of sewer extensions, ugly, malodorous and useless for fishing or recreation. Then San. Dist. Law passed establishing non-partisan san. bd. to handle Indianapolis sewage problem. Sewage treatment development in Ind. traced from 1898 to '13. Present stream poln. bd. equally divided between 2 principal political parties and hopes to proceed on scientific and sound economic basis.—*Ralph E. Noble.*

Red River of the North Research Investigation. N.D. Dept. Health ('42). Joint investigation of Red R. by N.D. Dept. of Health and Minn. State Bd. of Health, in collaboration with U.S.P.H.S., '38 to '41, to det: (1) O_2 relationships in stream before and during ice coverage; (2) O_2 depletion rate in stream during ice coverage; (3) suitability of relatively unpold. streams for diln. purposes and characteristics and quants. of various wastes entering river. *General Conclusions:* Under ice coverage, D.O. content of river depleted to zero in few weeks except where dam-generated aeration exerted appreciable influence. With 200-cfs. flows, very unsatisfactory conditions prevailed below Grand Forks during winter critical period. Quant. and nature of entering wastes such that, without addnl. treatment, amt. of diln. water reasonably provided would not solve poln. problem. High stream flows accompanied by less septic conditions than low; less septic condition, however, resulted not only from increased diln., but also increased stream veloc. During winter and summer critical periods, flows from tributaries, except Red Lake, Ottertail, Sheyenne, Buffalo, and Minn. Wild Rice Rivers, insignif. as to poln. contributed and diln. provided. Less than 12′ high overflow dams of Red and Red Lake Rivers can provide sufficient aeration to increase D.O. of low-temp. O_2-deficient water to approx. 6 ppm. As summer D.O. values not found less than 6 ppm. at these dams no information thereof collected during summer. Undoubtedly, changed design would improve their aerating eff. Due to natural poln. alone, i.e., not receiving munic. or indus. waste discharges, O_2 content of water stored in reservoirs or river channels likely to be diminished seriously or depleted entirely. To be of greatest value for diln. purposes during winter critical season, therefore, impounded waters should be aerated upon release from reservoirs. Sludge deposits appear to exert appreciable effect. During periods of higher flow, org. material deposited at lower flows dislodged and poln. loading increased. At flows less than those required to dislodge sludge, however, poln. load may be increased by direct soln. of deposited org. matter of O_2-requiring decompn. products of anaerobic sludge digestion. Entrainment of material floated by gas from digestion processes observed. Relatively unpold. streams may, due to natural poln. alone, become completely devoid of D.O. during ice coverage period. Research information indicates rate and extension of O_2 utilization by indus. wastes depends upon variable factors including nature of waste, temp., extent of diln. and type of diln. water. Essential to det. not only basic behavior of each indus. waste separately, but also its effect in combination with other wastes under specific stream conditions. As indus. waste behavior may be quite different than that of domestic sewage, evident fallacy to forecast indus. wastes' effect on basis of domestic sewage behavior. Cumulative stream flow requirements in cfs. calcd. for summer, Oct. and winter at Fargo; and at Grand Forks without beet sugar wastes and same with such wastes, under conditions of existing wastes treatment and under those with 85% treatment.—*Ralph E. Noble.*

Water Conservation in Philadelphia

By Martin J. McLaughlin

IN 1942 the Water Conservation Program of the Philadelphia Metropolitan Area was participated in by five counties comprising this district—Philadelphia, Delaware, Chester, Montgomery and Bucks Counties. This program was approved and carried the endorsement of the County Council of Defense in this metropolitan district who co-operated whole-heartedly in this campaign. We are indebted to the Interstate Commission of the Delaware River Basin, the Chester Municipal Authority Water Service and the Municipal Water Works of Coatesville, Pa., who took an active part in the plans.

There were 750,000 four-page leaflets distributed to homes in the district as well as 80,000 printed posters which were distributed to all plants using large amounts of water, as well as stores, schools and business houses. The distribution in Philadelphia of 500,000 leaflets was made to all homes, apartment houses and office buildings by inspectors of the Bureau of Highways. The posters, 40,000 in number, were distributed by the Police Department.

Publicity for the drive was released through the press, radio, schools and civic organizations.

The success of the program was due in large part to the fact that we stressed the patriotic duty of citizens to conserve water rather than resort to coercion or threats.

In 1941 the average daily consumption for the city of Philadelphia alone was 327 mil.gal. The maximum day in 1941 was in September—336.7 mil.gal.

Prior to the advent of peak demands for the year 1942 it was estimated that with an increase of population of 250,000 war workers, plus the added load of 25 per cent increase by war defense plants, we would be called on to furnish about 360 mgd.

In Philadelphia the average daily consumption for the year 1942, in spite of the added demand, was 315 mil.gal. The maximum day was in September with 324 mil.gal. In the metropolitan district there was a daily saving of 65 mil.gal.

Once the campaign was under way, we began to receive complaints from householders who notified us of neighbors who were wasting water. Tenants also complained of leaking faucets and faulty plumbing. The Inspection Division served notices on all these locations, and within a week of the serving of the notices, a re-check by our inspectors showed that there was a 100 per cent compliance with requests to remove the sources of complaints.

A contribution by Martin J. McLaughlin, Chief of Bureau of Water, Dept. of Public Works, Philadelphia, Pa.

For the year 1943 our average daily consumption figure was 322 mil.gal.

We feel that, while there has been an increase for this period over 1942, the wide use of victory gardens and the restrictions on the use of gasoline, which prevented a large percentage of the population from leaving the city of Philadelphia over week ends and during the vacation period, were responsible for the slight increase. This is borne out by a sharp decrease in consumption noted during the week ends of the Fourth of July and Labor Day, when figures were about the same as those for the same dates in 1942.

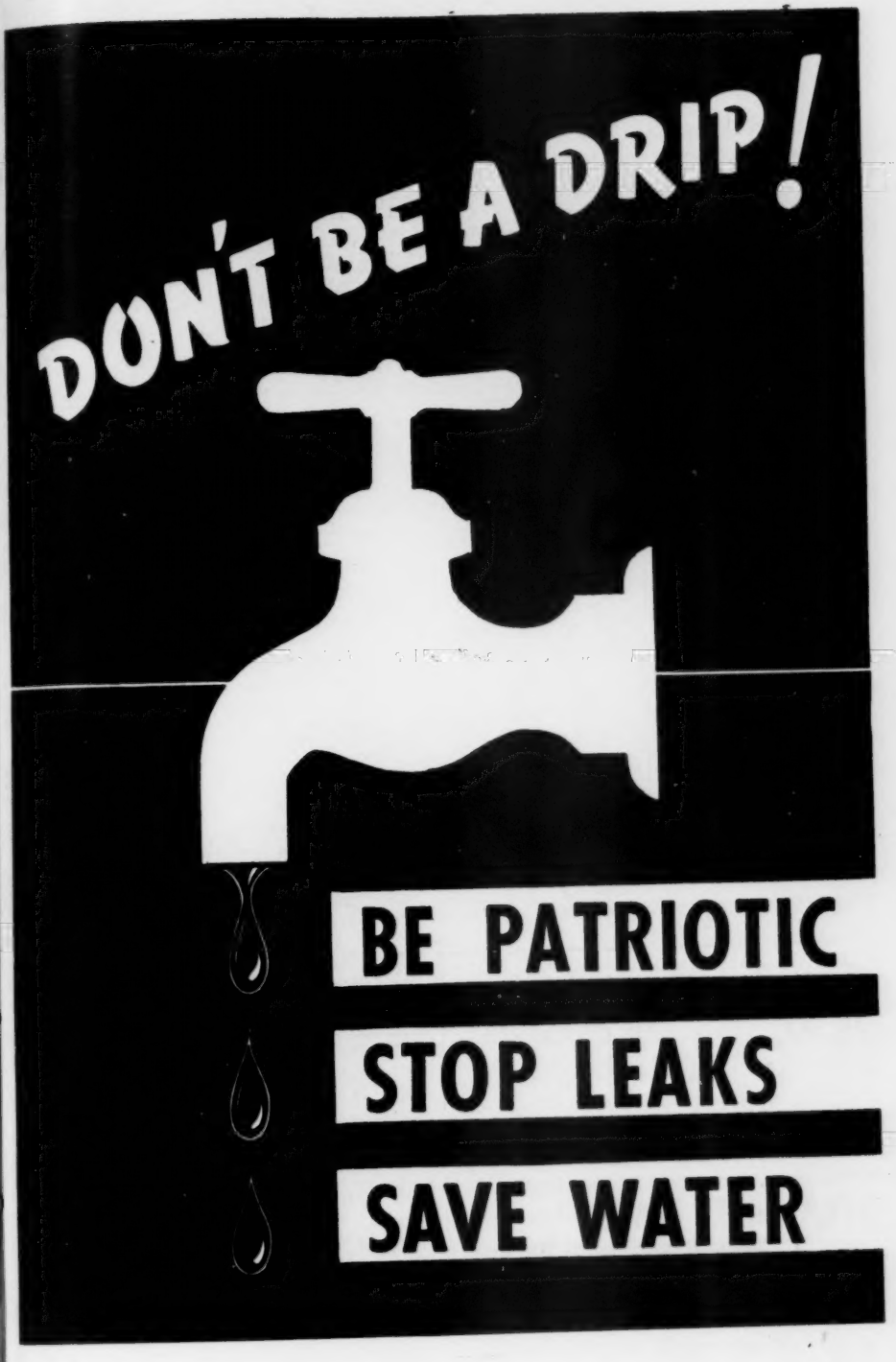
This campaign was of such importance in the opinion of the present administration that the mayor, who took an active part in the campaign, allotted the necessary funds to the Bureau of Water to continue a pitometer survey on underground leaks and the under-registration of meters, of sizes 4 in. and over, for 1943 and 1944.

Since Philadelphia and the metropolitan district showed great savings due to this water conservation program, it can be well imagined what results may be obtained from the nation-wide program, as now instituted by the federal government.

The mayor has appointed a Committee for 1944 on Conservation of Critical Resources. This committee is now planning a "stop waste" program for the year which will include water conservation.

The poster shown on page 499, is one of four included in the A.W.W.A. Water Conservation book, and was originally designed for the Philadelphia campaign by The Interstate Commission on the Delaware River Basin.

It comes in three colors—red, blue and yellow—and can be ordered in any quantity desired, by writing to the American Water Works Association, 500 Fifth Avenue, New York, 18, N. Y.


DON'T BE A DRIP!
BE PATRIOTIC
STOP LEAKS
SAVE WATER

Willing Water Takes a Bow in Jackson

HOW the Jackson Water Works, Jackson, Miss., made use of the character Willing Water, and illustrations from the book *Water Conservation,* is told in the following excerpt from a letter written to the A.W.W.A., by Baxter F. Wade, Superintendent of the Jackson plant:

"Enclosed herewith you will find 2 folders which we have used in carrying out the water conservation program in co-operation with the War Production Board. These have been used as inserts in the regular billing for the past 2 months.

Both sides of one of the folders which Mr. Wade mentions, are shown here. The leaflet is 3 x 5 in. when folded, and is printed on white paper, in red and blue ink—very patriotic in appearance!

WILLING WATER SAYS
THIS IS A LEAKY FAUCET
IT WASTES 970 GALLONS OF WATER A DAY
IT NEEDS THIS NEW WASHER
SAYS WILLING WATER
AND THIS IS THE WRENCH
TO FIX THE LEAKY FAUCET
COME ON FOLKS LETS STOP ALL LEAKS TO HELP WIN THE WAR
Use Water Usefully — Stop Waste And Leaks — You'll Save On Water Bill

Water Will NOT Be Rationed So Use ALL You Need, But DON'T WASTE IT!
Jackson City Water Has Gone To War—At The Army Air Base, Army Hospital, War Plants, War Workers Homes And Other Places
STOP WATER LEAKS
And Keep Every Drop At War Work
SEE INSIDE
We Cooperate—
The U.S. War Production Board has called upon all American citizens to cooperate in a national water conservation program designed to save manpower materials etc. for the war effort.
Plans for this program have been formulated by the American Water Works Association, and as a member, the Jackson Water Works is lending its fullest cooperation.
In this, and succeeding messages, we are indicating how Jackson citizens can also patriotically give valuable assistance to this important war program. Together, we shall serve our country in this as in all other war efforts.
Jackson Water Works
B. F. WADE, Superintendent
WALTER A. SCOTT, Mayor
Here's HOW You Can Help Uncle Sam And YOUR OWN POCKET BOOK
LOOK